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## SOCIETY AN ORGANISM.[1]

BY HERBERT SPENCER.

THE question, What is a society? has to be asked and answered at the outset. Until we have decided whether or not to regard a society as an entity, and until we have decided whether, if regarded as an entity, a society is to be classed as absolutely unlike all other entities or as like some others, our conception of the subject-matter before us remains vague.

It may be said that a society is but a collective name for a number of individuals. Carrying the controversy between nominalism and realism into another sphere, a nominalist might affirm that, just as there exist only the members of a species, while the species considered apart from them has no existence, so the units of a society alone exist, while the existence of the society is but verbal. Instancing a lecturer's audience as an aggregate which, by disappearing at the close of the lecture, proves itself to be not a thing but only a certain arrangement of persons, he might argue that the like holds of the citizens forming a nation.

But, without disputing the other steps of his argument, the last step may be denied. The arrangement, temporary in one case, is lasting in the other; and it is the permanence of the relations among component parts which constitutes the individuality of a whole as distinguished from the individualities of its parts. A coherent mass broken into fragments ceases to be a thing; while, conversely, the stones, bricks, and wood, previously separate, become the thing called a house if connected in fixed ways.

Thus we consistently regard a society as an entity, because, though formed of discrete units, a certain concreteness in the aggregate of

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[1] From advance-sheets of the "Principles of Sociology," Part II., "The Inductions of Sociology."

them is implied by the maintenance, for generations and centuries, of a general likeness of arrangement throughout the area occupied. And it is this trait which yields our idea of a society. For, withholding the name from an ever-changing cluster such as primitive men form, we apply it only where some constancy in the distribution of parts has resulted from settled life.

But now, regarding a society as a thing, what kind of a thing must we call it? It seems totally unlike every object with which our senses acquaint us. Any likeness it may possibly have to other objects cannot be manifest to perception, but can be discerned only by reason. If the constant relations among its parts make it an entity, the question arises whether these constant relations among its parts are akin to the constant relations among the parts of other entities. Between a society and anything else, the only conceivable resemblance must be one due to *parallelism of principle in the arrangement of components.*

There are two great classes of aggregates with which the social aggregate may be compared—the inorganic and the organic. Are the attributes of a society, considered apart from its living units, in any way like those of a not-living body? or are they in any way like those of a living body? or are they entirely unlike those of both?

The first of these questions needs only to be asked to be answered in the negative. A whole of which the parts are alive cannot, in its general characters, be like lifeless wholes. The second question, not to be thus promptly answered, is to be answered in the affirmative. The reasons for asserting that the permanent relations among the parts of a society are analogous to the permanent relations among the parts of a living body, we have now to consider.

When we say that growth is common to social aggregates and organic aggregates, we do not thus entirely exclude community with inorganic aggregates: some of these, as crystals, grow in a visible manner; and all of them, on the hypothesis of evolution, are concluded to have arisen by integration at some time or other. Nevertheless, compared with things we call inanimate, living bodies and societies so conspicuously exhibit augmentation of mass that we may fairly regard this as characteristic of them both. Many organisms grow throughout their lives, and the rest grow throughout considerable parts of their lives. Social growth usually continues either up to times when the societies divide, or up to times when they are overwhelmed.

Here, then, is the first trait by which societies ally themselves with the organic world, and substantially distinguish themselves from the inorganic world.

It is also a character of social bodies, as of living bodies, that while they increase in size they increase in structure. A low animal, or the embryo of a high one, has few distinguishable parts; but along with its acquirement of greater mass its parts multiply and simultaneously differentiate. It is thus with a society. At first the unlikenesses among its groups of units are inconspicuous in number and degree; but, as it becomes more populous, divisions and subdivisions become more numerous and more decided. Further, in the social organism as in the individual organism, differentiations cease only with that completion of the type which marks maturity and precedes decay.

Though in inorganic aggregates also, as in the entire solar system and in each of its members, structural differentiations accompany the integrations, yet these are so relatively slow, and so relatively simple, that they may be disregarded. The multiplication of contrasted parts in bodies politic and in living bodies is so great that it substantially constitutes another common character which marks them off from inorganic bodies.

This community will be more fully appreciated on observing that progressive differentiation of structures is accompanied by progressive differentiation of functions.

The multiplying divisions, primary, secondary, and tertiary, which arise in a developing animal, do not assume their major and minor unlikenesses to no purpose. Along with diversities in their shapes and compositions there go diversities in the actions they perform: they grow into unlike organs having unlike duties. Assuming the entire function of absorbing nutriment at the same time that it takes on its structural characters, the alimentary system becomes gradually marked off into contrasted portions, each of which has a special function forming part of the general function. A limb, instrumental to locomotion or prehension, acquires divisions and subdivisions which perform their leading and their subsidiary shares in this office. So is it with the parts into which a society divides. A dominant class arising does not simply become unlike the rest, but assumes control over the rest; and when this class separates into the more and the less dominant, these, again, begin to discharge distinct parts of the entire control. With the classes whose actions are controlled it is the same. The various groups into which they fall have various occupations, each of such groups also, within itself, acquiring minor contrasts of parts along with minor contrasts of duties.

And here we see more clearly how the two classes of things we are comparing distinguish themselves from things of other classes; for such differences of structure as slowly arise in inorganic aggregates are not accompanied by what we can fairly call differences of function.

Why in a body politic and in a living body these unlike actions of unlike parts are properly regarded by us as functions, while we cannot so regard the unlike actions of unlike parts in an inorganic body, we shall perceive on turning to the next and most distinctive common trait.

Evolution establishes in them both, not differences simply, but definitely-connected differences—differences such that each makes the others possible. The parts of an inorganic aggregate are so related that one may change greatly without appreciably affecting the rest. It is otherwise with the parts of an organic aggregate or of a social aggregate. In either of these the changes in the parts are mutually determined, and the changed actions of the parts are mutually dependent. In both, too, this mutuality increases as the evolution advances. The lowest type of animal is all stomach, all respiratory surface, all limb. Development of a type having appendages by which to move about or lay hold of food can take place only if these appendages, losing power to absorb nutriment directly from surrounding bodies, are supplied with nutriment by parts which retain the power of absorption. A respiratory surface, to which the circulating fluids are brought to be aërated, can be formed only on condition that the concomitant loss of ability to supply itself with materials for repair and growth is made good by the development of a structure bringing these materials. So is it in a society. What we call with perfect propriety its organization has a necessary implication of the same kind. While rudimentary, it is all warrior, all hunter, all hut-builder, all tool-maker: every part fulfills for itself all needs. Progress to a stage characterized by a permanent army can go on only as there arise arrangements for supplying that army with food, clothes, and munitions of war, by the rest. If here the population occupies itself solely with agriculture and there with mining—if these manufacture goods while those distribute them—it must be on condition that, in exchange for a special kind of service rendered by each part to other parts, these other parts severally give due proportions of their services.

This division of labor, first dwelt on by political economists as a social phenomenon, and thereupon recognized by biologists as a phenomenon of living bodies, which they called the "physiological division of labor," is that which in the society, as in the animal, makes it a living whole. Scarcely can I emphasize sufficiently the truth that, in respect of this fundamental trait, a social organism and an individual organism are entirely alike. When we see that, in a mammal, arresting the lungs quickly brings the heart to a stand; that if the stomach fails absolutely in its office all other parts by-and-by cease to act; that paralysis of its limbs entails on the body at large death from want of food or inability to escape; that loss of even such small organs as the eyes deprives the rest of a service essential to their preservation—we cannot but admit that mutual dependence of parts is an essential characteristic. And when, in a society, we see that the workers in iron stop if the miners do not supply materials; that makers of clothes cannot carry on their business in the absence of those who spin and weave textile fabrics; that the manufacturing community will cease to act unless the food-producing and food-distributing agencies are acting; that the controlling powers, governments, bureaus, judicial officers, police, must fail to keep order when the necessaries of life are not supplied to them by the parts kept in order—we are obliged to say that this mutual dependence of parts is similarly rigorous. Unlike as the two kinds of aggregates are in sundry respects, they are alike in respect of this fundamental character, and the characters implied by it.

How the combined actions of mutually-dependent parts constitute life of the whole, and how there hence results a parallelism between national life and individual life, we see still more clearly on learning that the life of every visible organism is constituted by the lives of units too minute to be seen by the unaided eye.

An undeniable illustration is furnished us by the strange order *Myxomycetes*. The spores or germs produced by one of these forms become ciliated monads which, after a time of active locomotion, change into shapes like those of amœbæ, move about, take in nutriment, grow, multiply by fission. Then these amœba-form individuals swarm together, begin to coalesce into groups, and these groups to coalesce with one another, making a mass sometimes barely visible, sometimes as big as the hand. This *plasmodium*, irregular, mostly reticulated, and in substance gelatinous, itself exhibits movements of its parts like those of a gigantic rhizopod, creeping slowly over surfaces of decaying matters and even up the stems of plants. Here, then, union of many minute living individuals to form a relatively vast aggregate in which their individualities are apparently lost, but the life of which results from combination of their lives, is demonstrable.

In other cases, instead of units which, originally discrete, lose their individualities by aggregation, we have units which, arising by multiplication from the same germ, do not part company, but nevertheless display their separate lives very clearly. A growing sponge has its horny fibres clothed with a gelatinous substance, and the microscope shows this to consist of moving monads. We cannot deny life to the sponge as a whole, for it shows us some corporate actions. The outer amœba-form units partially lose their individualities by fusion into a protective layer or skin; the supporting framework of fibres is produced by the joint agency of the monads, and from their joint agency also result those currents of water which are drawn in through the small orifices and expelled through the larger. But, while there is thus shown a feeble aggregate life, the lives of the myriads of component units are very little subordinated: these units form, as it were, a nation having scarcely any subdivision of functions. Or, in the words of Prof. Huxley, "the sponge represents a kind of subaqueous city, where the people are arranged about the streets and roads in such a manner that each can easily appropriate his food from the water as it passes along."

Even in the highest animals there remains traceable this relation between the aggregate life and the lives of components. Blood is a liquid in which, along with nutritive matters, circulate innumerable living units—the blood-corpuscles. These have severally their life-histories. During its first stage each of them, then known as a white corpuscle, makes independent movements like those of an amœba; and though in its adult stage, as a red, flattened disk, it is not visibly active, its individual life continues. Nor is this individual life of the units provable only where free flotation in a liquid allows its signs to be readily seen. Sundry mucous surfaces, as those of the air-passages, are covered with what is called ciliated epithelium—a layer of minute cells packed side by side, and each bearing on its exposed end several cilia continually in motion. The wavings of these cilia are essentially like those of the monads which live in the passages running through a sponge; and just as the joint action of these ciliated sponge monads propels the current of water, so does the joint action of the ciliated epithelium-cells move forward the mucous secretion covering them. If there needs further proof of the individual lives of these epithelium-cells, we have it in the fact that, when detached and placed in fluid, they "move about with considerable rapidity for some time, by the continued vibrations of the cilia with which they are furnished."

On thus seeing that an ordinary living organism may be regarded as a nation of units that live individually, and have many of them considerable degrees of independence, we shall perceive how truly a nation of human beings may be regarded as an organism.

The relation between the lives of the units and the life of the aggregate has a further character common to the two cases. By a catastrophe the life of the aggregate may be destroyed without immediately destroying the lives of all its units; while, on the other hand, if no catastrophe abridges it, the life of the aggregate immensely exceeds in length the lives of its units.

In a cold-blooded animal, ciliated cells perform their motions with perfect regularity long after the creature they are part of has become motionless; muscular fibres retain their power of contracting under stimulation; the cells of secreting organs go on pouring out their product if blood is artificially supplied to them; and the components of an entire organ, as the heart, continue their coöperation for many hours after its detachment. Similarly, arrest of those commercial activities and governmental coördinations, etc., which constitute the corporate life of a nation, may be caused, say by an inroad of barbarians, without immediately stopping the actions of all the units. Certain classes of these, especially the widely-diffused ones engaged in food-production, may, in the remoter districts, long survive and carry on their individual occupations.

Conversely, in both cases, if not brought to a close by violence, the life of the aggregate greatly exceeds in duration the lives of its units. The minute living elements composing a developed animal severally evolve, play their parts, decay, and are replaced, while the animal as a whole continues. In the deep layer of the skin, cells are formed by fission, which, as they enlarge, are thrust outward, and, becoming flattened to form the epidermis, eventually exfoliate, while the younger ones beneath take their places. Liver-cells, growing by imbibition of matters from which they separate the bile, presently die, and their vacant seats are occupied by another generation. Even bone, though so dense and seemingly inert, is permeated by blood-vessels carrying materials to replace old components by new ones. And the replacement, rapid in some tissues and in others slow, goes on at such rate that, during the continued existence of the entire body, each portion of it has been many times over produced and destroyed. Thus it is also with a society and its units. Integrity of the whole and of each large division is perennially maintained, notwithstanding the deaths of component citizens. The fabric of living persons, which, in a manufacturing town, produces some commodity for national use, remains after a century as large a fabric, though all the masters and workers who a century ago composed it have long since disappeared. Even with the minor parts of this industrial structure the like holds. A firm that dates from past generations, still carrying on business in the name of its founder, has had all its members and employés changed one by one, perhaps several times over, while the firm has continued to occupy the same place and to maintain like relations to buyers and sellers. Throughout we find this. Governing bodies, general and local, ecclesiastical corporations, armies, institutions of all orders down to guilds, clubs, philanthropic associations, etc., show us a continuity of life exceeding that of the persons constituting them. Nay, more. As part of the same law, we see that the existence of the society at large exceeds in duration that of some of these compound parts. Private unions, local public bodies, secondary national institutions, towns carrying on special industries, may decay, while the nation, maintaining its integrity, evolves in mass and structure.

In both cases, too, the mutually-dependent functions of the various divisions, being severally made up of the actions of many units, it results that these units, dying one by one, are replaced without the function in which they share being sensibly affected. In a muscle each sarcous element wearing out in its turn is removed, and a substitution made while the rest carry on their combined contractions as usual; and the retirement of a public official or death of a shopman perturbs inappreciably the business of the department or activity of the industry in which he had a share.

Hence arises in the social organism, as in the individual organism, a life of the whole quite unlike the lives of the units, though it is a life produced by them.

From these likenesses between the social organism and the individual organism, we must now turn to an extreme unlikeness. The parts of an animal form a concrete whole, but the parts of a society form a whole that is discrete. While the living units composing the one are bound together in close contact, the living units composing the other are free, not in contact, and more or less widely dispersed. How, then, can there be any parallelism?

Though this difference is fundamental and apparently puts comparison out of the question, yet examination proves it to be less than it seems. Presently I shall have to point out that complete admission of it consists with maintenance of the alleged analogy; but we will first observe how one who thought it needful might argue that even in this respect there is more kinship than a cursory glance shows.

He might urge that the physically-coherent body of an animal is not composed all through of living units, but that it consists in large measure of differentiated parts which the vitally active parts have formed, and which thereafter become semi-vital and in some cases almost un-vital. Taking as an example the protoplasmic layer underlying the skin, he might say that, while this consists of truly living units, the cells produced in it, changing into epithelium-scales, become inert protective structures; and, pointing to the insensitive nails, hair, horns, and teeth, arising from this layer, he might show that such parts, though components of the organism, are hardly living components. Carrying out the argument, he would contend that elsewhere in the body there exist such protoplasmic layers, from which grow the tissues composing the various organs—layers which alone remain fully alive, while the structures evolved from them lose their vitality in proportion as they are specialized: instancing cartilage, tendon, and connective tissue, as showing in conspicuous ways this low vitality. From all which he would draw the inference that, though the body forms a coherent whole, its essential units, taken by themselves, form a whole which is coherent only throughout the protoplasmic layers.

And then would follow the argument that the social organism, rightly conceived, is much less discontinuous than it seems. He would contend that, as in the individual organism we include with the fully living parts the less living and not living parts which coöperate in the total activities, so, in the social organism, we must include not only those most highly-vitalized units, the human beings, who chiefly determine its phenomena, but also the various kinds of domestic animals, lower in the scale of life, which under the control of man coöperate with him, and even those far inferior structures the plants, which, propagated by human agency, supply materials for animal and human activities. In defense of this view he would point out how largely these lower classes of organisms, coexisting with men in societies, affect the structures and activities of the societies—how the traits of the pastoral type depend on the natures of the creatures reared; and how, in settled societies, the plants producing food, materials for textile fabrics, etc., determine certain kinds of social arrangements and actions. After which he might insist that, since the physical characters, mental natures, and daily activities, of the human units are in part moulded by relations to these animals and vegetables which, living by their aid, and aiding them to live, enter so much into social life as even to be cared for by legislation, these lower living things cannot rightly be excluded from the conception of the social organism. Hence would come his conclusion that when, with human beings, are incorporated the less vitalized beings, animal and vegetal, covering the surface occupied by the society, an aggregate results having a continuity of parts, more nearly approaching to that of an individual organism, and which is also like it in being composed of local aggregations of highly-vitalized units, imbedded in a vast aggregation of units of various lower degrees of vitality, which are in a sense produced by, modified by, and arranged by, the higher units.

But without accepting this view, and admitting that the discreteness of the social organism stands in marked contrast with the concreteness of the individual organism, the objection may still be adequately met.

Though coherence among its parts is a prerequisite to that coöperation by which the life of an individual organism is carried on, and though the members of a social organism, not forming a concrete whole, cannot maintain coöperation by means of physical influences directly propagated from part to part, yet they can and do maintain coöperation by another agency. Not in contact, they nevertheless affect one another through intervening spaces, both by emotional language, and by the language, oral and written, of the intellect. For carrying on mutually dependent actions it is requisite that impulses, adjusted in their kinds, amounts, and times, shall be conveyed from part to part. This requisite is fulfilled in living bodies by molecular waves, that are indefinitely diffused in low types, and in high types are carried along definite channels (the function of which has been significantly called *internuncial*). It is fulfilled in societies by the signs of feelings and thoughts, conveyed from person to person; at first in vague ways and only at short distances, but afterward more definitely and at greater distances. That is to say, the internuncial function, not achievable by stimuli physically transferred, is nevertheless achieved by language.

The mutual dependence of parts which constitutes organization is thus effectually established. Though discrete instead of concrete, the social aggregate is rendered a living whole.

But now, on pursuing the course of thought opened by this objection and the answer to it, we arrive at an implied contrast of great significance—a contrast fundamentally affecting our idea of the ends to be achieved by social life.

Though the discreteness of a social organism does not prevent subdivision of functions and mutual dependence of parts, yet it does prevent that differentiation by which one part becomes an organ of feeling and thought, while other parts become insensitive. High animals, of whatever class, are distinguished from low ones by complex and well-integrated nervous systems. While in inferior types the minute scattered ganglia may be said to exist for the benefit of other structures, the concentrated ganglia in superior types are the structures for the benefit of which the rest may be said to exist. Though a developed nervous system so directs the actions of the whole body as to preserve its integrity, yet the welfare of the nervous system is the ultimate object of all these actions, damage to any other organ being serious only because it immediately or remotely entails that pain or loss of pleasure which the nervous system suffers. But the discreteness of a society negatives differentiations carried to this extreme. In an individual organism the minute living units, most of them permanently localized, growing up, working, reproducing, and dying away in their respective places, are in successive generations moulded to their respective functions, so that some become specially sentient and others entirely insentient. But it is otherwise in a social organism. The units of this, out of contact and much less rigidly held in their relative positions, cannot be so much differentiated as to become feelingless units and units which monopolize feeling. There are, indeed, slight traces of such a differentiation. Human beings are unlike in the amounts of sensation and emotion producible in them by like causes: here great callousness, here great susceptibility, is characteristic. In the same society, even where its members are of the same race, and still more where its members are of dominant and subject races, there exists a contrast of this kind. The mechanically-working and hard-living units are less sensitive than the mentally-working and more protected units. But while the regulative structures of the social organism tend, like those of the individual organism, to become seats of feeling, the tendency is checked by this want of physical cohesion which brings fixity of function; and it is also checked by the continued need for feeling in the mechanically-working units for the due discharge of their functions.

Hence, then, a cardinal difference in the two kinds of organisms. In the one, consciousness is concentrated in a small part of the aggregate. In the other, it is diffused throughout the aggregate: all the units possess the capacities for happiness and misery, if not in equal degrees, still in degrees that approximate. As, then, there is no social sensorium, it results that the welfare of the aggregate, considered apart from that of the units, is not an end to be sought. The society exists for the benefit of its members; not its members for the benefit of the society. It has ever to be remembered that great as may be the efforts made for the prosperity of the body politic, yet the claims of the body politic are nothing in themselves, and become something only in so far as they embody the claims of its component individuals.

From this last consideration, which is a digression rather than a part of the argument, let us now return and sum up the various reasons for regarding a society as an organism.

It undergoes continuous growth; as it grows, its parts, becoming unlike, exhibit increase of structure; the unlike parts simultaneously assume activities of unlike kinds; these activities are not simply different, but their differences are so related as to make one another possible; the reciprocal aid thus given causes mutual dependence of the parts; and the mutually-dependent parts, living by and for one another, form an aggregate constituted on the same general principle as an individual organism. The analogy of a society to an organism becomes still clearer on learning that every organism of appreciable size is a society, and on further learning that, in both, the lives of the units continue for some time if the life of the aggregate is suddenly arrested, while if the aggregate is not destroyed by violence its life greatly exceeds in duration the lives of its units. Though the two are contrasted as respectively discrete and concrete, and though there results a difference in the ends subserved by the organization, there does not result a difference in the laws of the organization: the required mutual influences of the parts, not transmissible in a direct way, being transmitted in an indirect way.

Having thus considered in their most general forms the reasons for regarding a society as an organism, we are prepared for following out the comparison in detail. We shall find that the further we pursue it the closer does the analogy appear.

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# HAMMERS AND PERCUSSION.

By the Rev. ARTHUR RIGG, M. A.

THE only mechanical tools for external use with which man is provided by Nature are: the hammer, a compound vise, and a scratching or scraping tool; these are all in the hand. As a vise, the hand is worthy of a very lengthened notice; as a hammer alone it is now our concern. While upon a substance softer than itself the fist can deal an appreciable blow, with one harder than itself the reaction of the substance transfers the blow to the flesh and bone of Nature's hammer. Hence early arose the necessity of an artificial hammer of stone or other hard substance.

[1] Abstract of three lectures before the London Society of Arts.

Among the contrivances which have come down to us from the ages before history was written, or the use of metals known, are found stones shaped, as we may suppose, by the action of water, and so rounded as to fit the hand. These stones are called by antiquarians "mauls," and they were probably held in the hand and struck against objects which otherwise could not have been broken. The maul is the original form of the hammer. This maul might occasionally have proved too heavy, but more frequently too light. For that tapping action which in our minor wants is often more requisite than blows, our prehistoric ancestors seem to have devised an ingenious appliance consisting of a stone specially prepared for this somewhat delicate operation. (Fig. 1.)

Fig. 1.—Tapping-Hammer of Stone.

This is supposed to be one of these tapping-hammers, held between a finger and the thumb; the original bears traces of wear, as if it had been employed in striking against a cylindrical or sharp surface.

When, now, we pass from this light to very heavy work, it will be obvious that to hold a stone in the hollow of the hand, and to strike an object with it so that the reaction of the blow shall be mainly met by the muscular action of the back of the hand, and the thinnest section of the wrist, would be not only fatiguing, but might be injurious to the delicate network of muscles there found, and so damage this part of the hand. It may have been from such effects that even in the Stone age there are traces of mauls which have double ends and are held by the middle. A blow given by such is counteracted not only by the increased mass of material, but also by the changed position of the hand and wrist in relation to the direction of the blow. When held in the hollow of the hand, the reaction was met by (say) a depth of tissue of about three-quarters of an inch, but, when held as the maul now alluded to must have been held, this reaction is met by a depth of tissue of about three inches. Hence, while mechanically (owing to the mass of stone) and muscularly (owing to the position of the hand in reference to the direction of the blow) the maul in this second stage is a decided improvement upon its primitive form, we cannot but admit that experience would soon suggest that even thus there was wanting sufficient energy to overcome reactions, and that the double-headed maul might be improved.

The men of the Stone age early perceived the advantage of having a handle of some kind for their mauls, and doubtless their first expedient consisted in lashing withes around such mauls as were found suitable, as the blacksmith at the present day lashes withes round the heads of his cutting and punching tools and swages. Evidences of a further advance toward a perfect hammer are to be seen in stone mauls with holes through them suitable for handles; and these holes are in some instances coned, and as well adapted for hammer-handles as the best-made metal tools of our day.

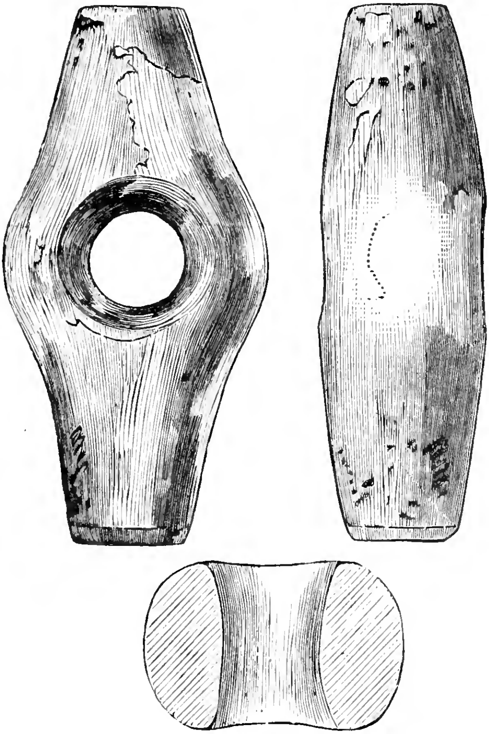


Fig. 2.—Perforated Hammer-Head of Stone.

Before inquiring into the reasons which may have led to the adoption of the various materials and forms of hammers now in use, it will be well to consider the hammer in, and of, and by itself. We are so apt to look upon it as a rude implement, necessarily associated with a superior class of finishing-tools, that the materials, forms, and scientific principles involved in its construction and use, not only as an adjunct to other tools, but as a sole independent and final tool, are much overlooked.

In some handicrafts, and those too involving a high class of finished work, the hammer is the only tool employed. That great artistic skill in the use of the hammer as a finishing-tool can be acquired, is manifest from the many beautiful specimens of *répoussé* work to be seen in silversmiths' shops. The details of the ornamentation are not only minute, but they so harmonize as to give elegance and expression to the whole, exclusive of the form of the articles themselves. The variety of shape is mainly produced by changes in the form of the "pane" of the hammer and in the weight of it. These changes of "pane" are sometimes effected by separating the pane from the hammer, and then the separated piece is called a "punch."

The famous shield of Achilles, in the "Iliad" of Homer, is described as the result of hammer-work; and, though this shield may not have been actually fashioned, nevertheless the description gives an idea of what a hammer was in early times poetically supposed to be capable of accomplishing. The scenes wrought upon the shield of Achilles are—1. The earth, sea, and heavenly bodies. 2. In a city at peace there are (*a.*) Marriage festivities; (*b.*) Judicial suit or trial. 3. In a city at war there are (*a.*) A scene before the ramparts; (*b.*) An ambush and surprise; (*c.*) A bloody fight. 4. The ploughing of a field. 5. The harvest and the meal in preparation. 6. The vintage, with music and a march. 7. A herd of cattle attacked by lions. 8. Sheep at pasture, and their folds. 9. A dance. 10. The great ocean-river encompassing the whole, as, in the mind of Homer, it encompassed the earth. For examples of the use of hammers in the production of works of great variety and extent on a large scale, see the ancient hammered wrought-iron gates, hinges, and panels, in the architectural room in the South Kensington Museum; also the suits of mail and chain-armor in the Tower of London; also the formation of gold-leaf, the springs of carriages, and the stiffening of saw-plates.

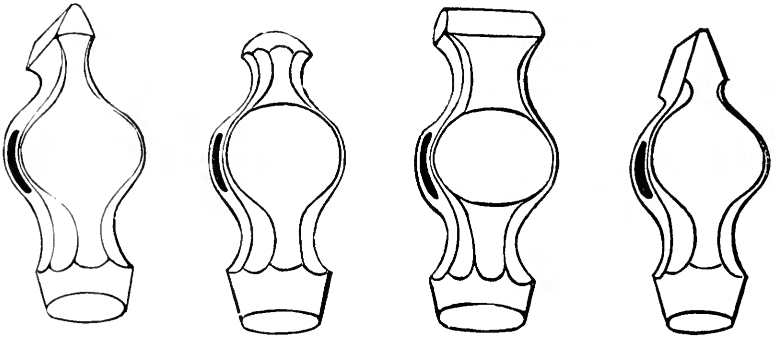


Fig. 3. Fig. 4. Fig. 5. Fig. 6.

Engineer's Hammers.

The nature of the work to be done by hammers calls for very great differences, not only in the form, material, and weight of the hammer-head, but also in the appendages to these. There are the material and form of the handles, the angle at which these handles should intersect the axial line of the hammer-head, the position of the centre of gravity with respect to the intersection of this axial line, the length and elasticity of the handle. If the centre of gravity is not in the central line or longitudinal axis of the hammer-head, then there is a tendency to bring the hammer down on the edge of the face and not on the face. If this defective construction were great, the muscles of the wrist might not be strong enough to counteract the tendency. If the defective construction is slight, then the work is often marked with angular indents. Arrangements, too, may be required for modifying the intensity of the blow, while retaining the effects resulting from a heavy hammer where a light one would be inefficient.

It is curious to see how in the same trade the hammers are for different purposes made of different materials. The engineer, for example, uses hammers faced with steel hardened, the stone-breaker (or mineralogist) hammers faced with steel softened (or rather not hardened). Again, in another part of his progressive work, the steel hammer with which the engineer commenced his operations gives place to a bronze or copper one, and this is sometimes displaced by one of lead alloyed with tin, and the handle entirely discarded.

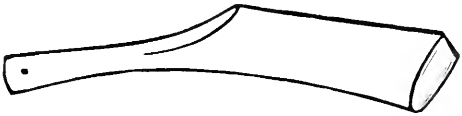


FIG. 7.

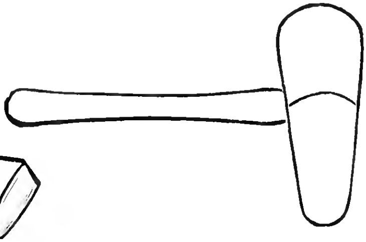


FIG. 8.

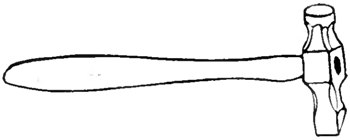


FIG. 9.

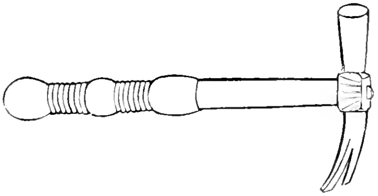


FIG. 10.

PLUMBER'S HAMMERS.

The plumber dismisses all these, and for direct action upon the material employed in his trade he uses a hammer of wood, discarding not only the material but also the form of hammers used in allied crafts. Indeed, one of his hammers (Fig. 7) serves a double purpose, for, if at one moment it is a hammer, at the next it is used as a swage. Fig. 9 is his ordinary hammer, but when carrying on his allied trade of a glazier, not content with this, even the handle (Fig. 10) is finished in an unusual manner, probably for convenience in holding putty, which he often carries "dabbed" on the handle. In some cases, as in the working of copper vessels which have been silver-plated or gilt, the coats of the precious metals are so thin that, although the weight of a hammer-head is required, yet even the wooden hammer of the plumber, or the still softer leaden hammer of the engineer, is equally unsuitable, and therefore the workers in these metals cover the face of their hammers at times with one or more layers of cloth.

The veneering hammer is compound, one end being formed of metal and the other of wood. The metal end is used as a squeezing-hammer (if such a term may be employed), and the wooden end as a tapping-hammer, to ascertain by the sound produced where the veneering is adhering and where it is not.

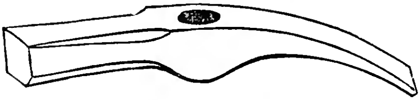


Fig. 11.—Mason's Hammer-Head.

The stone-mason seems to claim a universal choice. As to material, he has and frequently uses hammers made of wood, of iron (steel-faced), and of an alloy of lead.

In some cases the hammer and the anvil mutually change places, the hammer of wood, the anvil of metal, or the converse. Nor is the wood always of the same character. As varied as are the characters of the woods themselves, so varied are those chosen by different crafts for the employment of each craft.

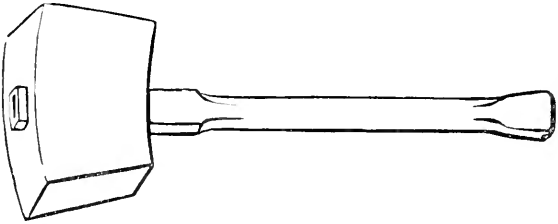
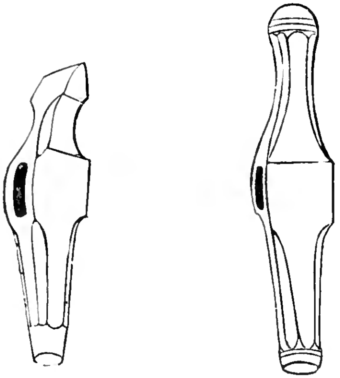


Fig. 12.—Carpenter's Wooden Mallet.

Hammers with and without handles are in use—hammers of various weights, from half an ounce to ten pounds, and from fifteen to fifty-six pounds are now employed as hand-hammers. The angles of attachment of handles to heads are various: the position of the centre of gravity of the head in reference to the line of penetration of the handle is various; the faces have various convexities; the panes have all ranges and forms, from the hemispherical end of the engineer's hammer, and the sharpened end of the pick and tomahawk, to the curved sharpened edge of the adze, or the straight convex edge of the hatchet and axe; the panes make all angles with the plane in which the hammer moves.



Figs. 13, 14.—Boiler-Maker's Hammers.

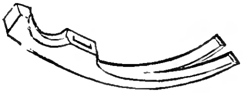


Fig. 15.—Cooper's Claw-Hammer.

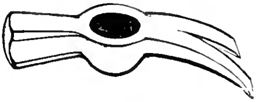


Fig. 16.—Ship-Carpenter's Claw-Hammer.

Fig. 16 is a ship-carpenter's hammer-head with claw. It differs from ordinary claw-hammers in that the handle is not strapped. In some American claw-hammers the strapping is carried up the back and front of the hammer. Why this change has been made is not very apparent, for by it one strap—that nearest the claw—is in tension, while the other is in compression. With the straps on the sides, as in Figs. 18, 19, the tension is equal on both. Fig. 15 is a cooper's claw-hammer, not strapped. In these cases, if much power is required when the claw is used, it should be applied by pressure on the face-end of the hammer as well as upon the handle.

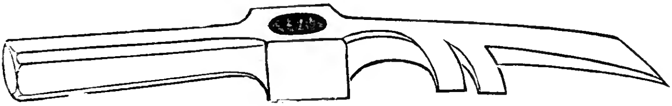


Fig. 17.—Coach-Trimmer's Hammer-Head.

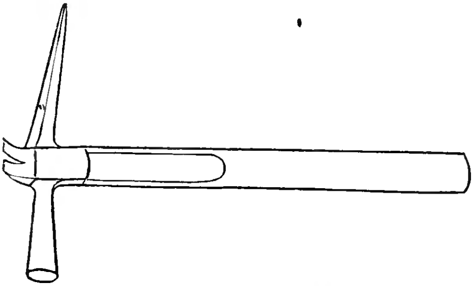


Fig. 18.—Slater's Hammer.

Before considering the elements upon a combination of which the powers of hand-hammers depend, it will be well to remark upon the circumstances under which this power is actually developed. The development takes place at the instant of contact of the moving hammer with the struck body. Such contacts as those of hammers belong to that department of mechanical philosophy called "impact." Impact is pressure of short duration—so short that, compared with the time in which the velocity of the impinging body is being acquired, it is inappreciable; or, if the comparison be between spaces passed through by the hammer-head before impact and during impact, then, generally speaking, the disproportion is the same, and the space passed through after impact is almost inappreciable when compared with the space passed through before impact.

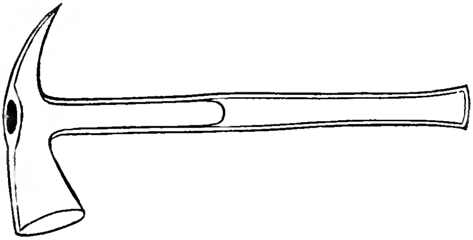


Fig. 19.—Tomahawk-Hammer.

It may assist in realizing the source as well as the magnitude of the power of a hammer, if the dynamical effect of impact be compared with what may be called the statical effect of pressure. Let any one attempt to drive a nail vertically into an horizontal piece of timber by the statical effect of the simple pressure of a load placed gently on the head, as weights are laid in scale-pans. Let the depth to which the nail is thus moved be measured. Again, let the same nail, under the same circumstances, be driven to the same depth by the impact of a hammer-head, then it may for our present purpose be said that the load placed on the nail is a representative statical measure of the impact of the hammer.

Now, although in any given case the work in a hammer consequent on its mass and velocity may be very great, yet utilizing the whole of the work produced in the expenditure of the accumulated power in the hammer depends upon the resistance met with at the instant of impact. The more perfect this resistance is, the greater will be the value of the work done; hence the practice of using massive anvils, firmly fixed, and the necessity for staying all vibrations in the body struck. Let any one attempt to drive a nail in a board not firmly supported, and then by the use of the same means drive a similar nail into the same board supported, and he will appreciate the importance of resistance to the progress of a hammer's motion if the full effect of a blow be desired.

The only exception to this is to be found in the blows given to minerals which are to be cleft, and not crushed. In their case it is desired to give only such a blow as shall accomplish the cleaving; any surplusage of energy, if expended on the material, would, of course, produce fractures over and above the required cleavage. Provision must be made for the dissipation of this superfluous energy, and it is done by placing the mineral in an elastic holding, the nature of the required elasticity being determined by experience, as different substances require different elasticities in the supports by which they are held for cleavage. Illustrations of the principle here enunciated are seen in the breaking of stones on the highway, where the elasticity is transferred from the mineral support to the handle of the hammer; also in the flaking of flints, where the elasticity is obtained by holding the mineral in the hand and supporting it on the knees. The splitting of the diamond is a case where these principles and considerations claim the greatest care.

The anvil used by the diamond-splitter is of wood, in shape not unlike a ninepin, but tapered at the lower end so as to be placed upright in a coned hole in a small block of lead. On the head of the ninepin is a flat, on which, by means of cement, the diamond to be split can be firmly fixed. Placed here so that the plane of intended cleavage shall be vertical when the wooden anvil is in the lead block, a deep scratch is made by a second diamond, in which scratch the edge of the splitter's chisel is to be planted. The diamond-splitter's chisel is very like an old razor. This chisel the workman holds in his left hand, in his right he holds that which is his hammer. The hammer is a plain steel rod, about eight inches in length, and tapering from about half an inch diameter in the middle to three-quarters of an inch at the end. The very construction of this peculiar hammer gives the operator a large range for precise and graduated blows; within certain limits he can most carefully arrange that the path of the centre of percussion, the place of impact, the line bisecting the angle of his razor-like chisel, and the expected plane of cleavage of the diamond, shall coincide; hence, with great coolness and the absence of all hesitation, he gives a blow, upon the effect of which many hundreds of pounds may depend.

In dealing with hammers—including under that term for the present purpose axes, hatchets, adzes, and picks—the following question claims consideration: What power or energy is in a hammer of known weight, moving at a known velocity, if brought to a state of rest by impact on a block? Another question also suggests itself: Can this impact effect of a hammer be converted into simple pressure, and be stated as a load or weight placed, where the impact was requisite, to produce the same effect as the impact did? If the mode of solving the first question can be made clear, then the answer to the second can be easily obtained. The measurable elements which affect the result are a variation in the mass of the hammer-head, and a variation in the length of the handle. By a varied mass there is a varied weight in the hammer; by a varied length of handle there will, with the same muscular effort, be a varied velocity in this mass, and upon a combination of mass and velocity depends the produced energy. Now, if a mass of metal, moving at a known velocity, strike an object, the energy of that blow results entirely from the conditions at the moment of impact. For example, the work in the hammer, *H*, as it strikes the nail, *N* (Fig. 20), does not depend upon its velocity through the arc, *Q N*, but only upon the velocity when commencing contact with the nail. Hence, so long as the material which gives the blow and the mass of it are the same, it is not of any consequence how the velocity was accumulated. It may result from centrifugal or rectilinear action; it may result from muscular effort, or from steam-pressure, or from gravity.

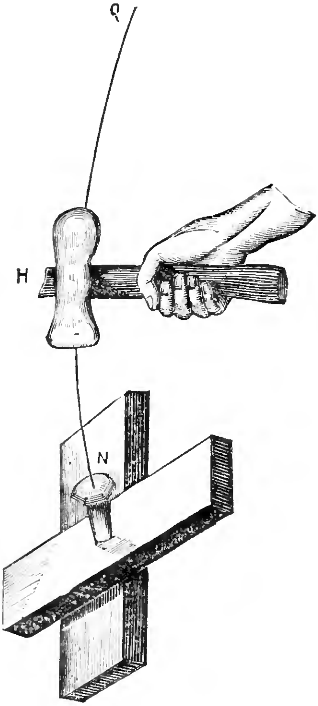


FIG. 20.

It may now be obvious that, other elements remaining unchanged, whatever accelerates the velocity of a hammer increases, according to very clear rules, the energy or power of the same hammer. Hence the tendency of contrivances, as manifested in the addition to steam as well as handicraft hammers; for example, in the early lift-hammers, those which are by many still considered to produce the most perfect of hammered work, the "wiper" was so shaped as to throw the hammer very high. The ascent was checked by a powerful spring, and thus the ascensional energy was reversed and added to the accelerating force of gravity downward; and so not only was the intensity of the blows increased, but their frequency also. This spring took the place of that muscular energy which brought the hammer down with intensified effect.

Hence, also, in steam-hammers, all muscular effect to intensify the blow is transferred to the steam, and all consequences of centrifugal action, whether from hand or tilt hammers at the ends of arms, are removed. Further, in steam-hammers nowadays, the steam operates to check as well as to intensify the blow. This checking action is called "cushioning," and it seems to do what an elastic handle does in a sledge-hammer: it relieves the rigid fabric or erection from jar or destruction. "Cushioning" is brought into play by admitting steam for the purpose of checking the intensity of the blow due to the action of gravity alone, or of steam combining with gravity upon the hammer. Hence the perfect control over large steam or air worked hammers, and the rapidity with which the intensity of the blow may be changed. Such control as this over a sledge-hammer is beyond our bodily powers. We may intensify the blow, but we cannot, except just experimentally, and for the purpose of display, bring the restraining power of the muscles to diminish the energy of the descending hammer.—*Journal of the Society of Arts.*

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# PREPOSSESSIONS FOR AND AGAINST THE SUPERNATURAL.

## A CRITICISM OF DR. CARPENTER.

By JAMES McCOSH, LL. D.,
PRESIDENT OF PRINCETON COLLEGE.

DR. CARPENTER is master of the domain which he has appropriated for the last age, that of physiology. He has done more than any living man, not exactly to advance, but to combine and expound, the discovered truths of his science. But he is ever impelled by his intellectual sharpness and his cultivated tastes to take excursions into other regions, and I am not sure whether he has there been so successful. In particular, as dwelling so near the territory of mind, he has ever been crossing into it. He has made a very careful survey of the border-country, and given us the result in his valuable work "Mental Physiology." Ever since the palmy days of mesmerism and table-turning, he has been enlarging on that "expectancy" and "prepossession" which have been so perverting the vision of many in their observation of facts. He will not be offended with me if I hint that it is just possible that he himself may unconsciously be under the influence of these, when, on finding how much can be explained by physiological processes, he imagines he can account in the same way for purely mental operations.

On some points Dr. Carpenter has been vigorously opposing the materialism of the day: "In reducing the thinking man to the level of a puppet, that moves according as its strings are pulled, the materialistic philosopher places himself in complete antagonism to the positive conviction, which, like that of the existence of an external world, is felt by every right-minded man, who does not trouble himself by speculating upon the matter, that *he really does possess a self-determining power*, which can rise above all the promptings of suggestion, and can, *within certain limits*, mould external circumstances to its own requirements instead of being completely subjugated by them."—("Mental Physiology," § 5.) By such utterances, worthy of the son of Lant Carpenter, of Bristol, he has gained the confidence of a number of anti-materialistic and religious men, who may find, however, that he is conducting them into a place between two armies where they are exposed to the fire of both. At this point he has been abandoned by the disciples of Bain, Huxley, and Tyndall, by M. Ribot, and the writers in the *Revue Scientifique*, the organ of the school in France who wonder that he should stop where he has. For, if material agency can generate so much, can account for imagination and genius generally, can explain our higher intellectual efforts of judgment and reasoning, can fashion conscience and gender the obligation of duty and the sense of guilt, and our reverence for the unseen and the sublime, why may it not also produce will, an operation evidently so swayed by causes? They who follow Dr. Carpenter will soon find that they have very insecure footing, and must either go forward and identify will, as they do intelligence, with material agency, or retreat so far back as to hold that there are many other operations, such as the discernment of higher truth and higher goodness, which cannot be derived from atoms. If there be such an agent as will—and I agree with Dr. Carpenter in thinking that consciousness testifies in its behalf—then we must provide a compartment for it, and we may place there reason and our ideas of the good, the infinite, and the perfect.

Dr. Carpenter's views of the attributes of the mind seem to me to be very inadequate. They were formed about the time when Hartley's "Observations on Man" and James Mill's "Analysis of the Human Mind" were reckoned the highest authorities among the Unitarians who felt Priestley's influence. Dr. Carpenter evidently looks upon the operations of the mind as composed of sensations and ideations. His view of both these is very insufficient. In all sense-perception, there is more than mere sensation considered as a feeling; there is knowledge of something extended. Then along with every perception there is consciousness of self as perceiving. According to the school of James Mill, sensation is a mere feeling, and ideation is a reproduced sensation. Memories, imaginations, conceptions, are all ideations; nay, judgments and reasonings are only combined ideations. The sense of duty is the product of association of ideations founded on sensations of pleasure and pain. Dr. Carpenter proceeds, in fact, on this psychology. But, to his credit, he draws back at a certain point. He stands up resolutely for a self-determining will which he places above both sensation and ideation. When asked for his proof, he appeals very legitimately to a "conviction" felt by every mind. But a like conviction certifies that there is vastly more than he sees in operations which he has passed over so lightly; that in memory the idea of time is involved, as every thing is remembered as happening in time past; that in imagination there is a wonderful arranging power; in conception, a grouping power; and in judgment, the discovery of relations such as those of identity, of quantity, and cause and effect, all diving deep into the depth of things, while the conscience gives us an entirely new idea, that of good and evil, and makes us feel that we owe duties to God and our fellow-men. He who overlooks these attributes may imagine that he can identify mental operations with physiological; but it is simply because he has not noticed the characteristic attributes of the human mind.

Dr. Carpenter did essential service to science, to religion, and I may add to common-sense, by exposing the alleged evidence in behalf of mesmerism and table-turning. He showed that, in regard to these phenomena, there were a "prepossession" and an "expectancy" which led persons to believe and affirm, without any valid proof, that they witnessed certain actions. I cannot see, however, that Dr. Carpenter has here unfolded any new truth, or that he has explained the nature of this "expectancy"—certainly no light can be thrown upon it by physiology. It is to be accounted for by purely mental causes, by a hasty judgment into which people are led by the association of ideas, guided by the wishes or feelings of the heart. If we have been accustomed to see two things together, on one of them presenting itself we are apt to look for the other, and believe that this other is present when we have no valid proof. It is thus that, associating the standing on a steep precipice with a fall, many tremble when placed there, even though there be no real danger. It is thus we account for the apparent deception of the senses. We rapidly infer that an object seen across an arm of the sea or a level plain is near, following the rule, usually correct, that an object is near when there are few visible objects between us and it. It is thus that a countryman, seated, and, as he feels, at rest, on a vessel leaving the quay, momentarily reasons that the quay is moving, as he has found that when he is at rest the object whose image passes over his eye is in motion. It is thus that when a person has come to us habitually at a certain hour, say the postman to deliver our letters, we may readily take some other person who appears at the time for him, and be ready to affirm or to swear that we saw him. It is thus that "the wish is father to the thought;" that is, we are inclined to believe what we wish and expect. It is thus, too, that in times of excitement, personal, political, and religious, we readily fall in with the fancies created by our fears and our hopes. Not only so, but a vivid idea reaching down from the brain may produce the same effect on the sensorium as the external object does through the sense of sight or hearing. Dr. Carpenter has seized an important truth in explaining in this way the erroneous declarations given by honest enough persons believing in mesmerism and spirit-rapping, and ever seeking for signs and wonders. He is right, too, in explaining how strong religious feelings may raise illusory expectations and beliefs, and that the testimony given by persons under their influence may be partial or valueless.

I think I discover proof that even scientific men may fall under the influence of this "prepossession" and "expectancy." I see an example of it in the way in which many of them account for our thoughts and resolutions: they call them reflex action. The discovery of the nature of automatic motion was one of the most important discoveries of the last age. An action goes along a nerve to the centre of a ganglion, and comes out in motion by another nerve: thus, if a frog's foot is pricked, it is immediately drawn in. Of much the same kind is the reflex action of the sensori-motor system. My nostrils are affected by a pungent substance, the action goes on to the sensorium, and a sneeze is the result. So far we have a well-understood process. But can we go on to explain in this way our special mental acts? The language used by some physiologists is fitted to leave the impression that all mental action is the reflex of some action from without, probably a sensation. Let us look at a case. I receive a letter informing me that a friend at a distance is in deep distress, needs me to defend him by my presence, my purse, and my counsel, against a false accusation, and I hasten to his assistance. Is all this merely a reflex action called forth by the appeal in the letter? Let us carefully inquire how much and how little physiology can explain. It can show how the writing in the letter, after passing through the eye, is reflected on the retina, thence carried through the optic nerve to the sensorium, thence it may be transmitted to the gray matter at the periphery of the brain, and produce there, it may be, some motion or new arrangement of the cells. But it can go no farther. When I understand the letter, when I comprehend the position of my friend, when I conclude that the accusation against him is false, when I feel that I ought to assist him, and for this purpose travel a long way and make many sacrifices, we have come to processes that cannot be explained by any external impulse; which can as little be accounted for by reflex action as they could by gravity or by chemical affinity. Then there are cases in which the action originates within, with no prompting from without. I awake in the morning and I think and conclude that some good cause, the cause of liberty, or of my country, or of religion, requires me to take a bold, decisive action, and I hasten to put my purpose in execution. How absurd to call this, with some physiologists, a reflex action! That able men should have fallen into this error can only be accounted for by a law of "expectancy;" they have explained so much by their law, and they think that they can explain everything.

Dr. Carpenter has unfolded, as Hume had done a century ago, the tendencies which predispose man to believe in preternatural occurrences. But are there no "prepossessions" and "expectations" which incline some scientific men in the present day to account for all things by natural agency, and prejudice them against calling in any thing preternatural? The business of science is to look into the causes of obvious or recondite phenomena, and, proceeding in the right method, they have discovered the natural causes of events which many regarded as supernatural. The men who have explained lightning and mysterious diseases, and resolved light into vibrations, and detected the composition of the sun's atmosphere, and of the distant stars, are led to spurn at the very idea of there being any thing which cannot be accounted for by mundane agency. Then they have seen, or heard, or read, of so many cases of religious pretension and imposture that they at once set down every reported case of divine interposition to illusion or delusion. Some have gone the length of maintaining that a miracle is not only an improbability, but an impossibility. A "prepossession" is produced, an "expectancy" is created, that the miracles of Scripture may be solved by some natural means. In the last age Paulus labored to prove that Jesus accomplished his cures by taking advantage of the secret agencies of Nature. But this theory has long ago been set aside by every one as inconsistent with the training, the position, and known character of Jesus. Then the mythic theory was started and stretched to its utmost capacity by Strauss; but it has been shown that no myths ever had the consistency, the purity, the spirituality of the gospel narratives, parables, and doctrines. Now it is averred that historical proof is wanting of the early date of the books of the New Testament. This objection has been met already by the great scholars of Germany, and is being met by Dr. Lightfoot and others among English-speaking divines. It is shown and is admitted that some of the epistles of Paul must have been written by their reputed author, and that they presuppose a belief throughout the Church of the leading events in Christ's life, and of a perfected system of evangelical belief. If the epistles are genuine, so must be the correlated Book of Acts, with its wonderful story of the spread of the gospel, the only "working hypothesis" to explain the facts. The synoptics bear internal marks of being genuine; give a consistent tale to account for the state of things as detailed by Paul and the Book of Acts; and have external testimony accumulating in their favor derived especially from the controversies with the early heretics. Even John's gospel is brought within a hundred years of our Lord's death, almost certainly in the first century, is shown to be as little inconsistent with the synoptics as Plato's Socrates is with Xenophon's Socrates, and breathes an air so superior to that of the Apostolic Fathers, that we see the one to be heaven-descended, the other to be the product of imperfect human nature at a time when the minds of Christians were saturated with divine truth. It is clear that the "expectancy" of accounting for the life of Christ by human causes has not yet been realized. "The Bible," as Beza said, "is an anvil which has worn out many hammers."

Every one knows that all men, scientific and unscientific, are liable to be swayed by prejudice, and Dr. Carpenter has not been able to throw much light on this subject by physiology. Even mathematicians may have their "personal equation." Philosophers, so called, and scientists have fallen under the influence of the idols of Bacon, and not a few other idols which have been set up since his time. Historical investigators, judges, and juries, are all aware of its existence, and should guard against it. We meet with it in our daily intercourse with our fellow-men, and make allowance for it. We see it in the village parties, in political contests, and in the rivalries of rank and trade. To every reality there is a counterfeit; corresponding to every truth there is a false appearance; if there be one Jehovah, there are many idols. Many, when they look to the dust of the conflict, are tempted to conclude that Truth cannot be found. But, notwithstanding all this, Truth can be found and won by those who court her in the right manner and the right spirit. It is to be remembered, however, that while we are required to demand evidence before yielding our conviction, all evidence is not of the same kind. "I receive mathematics," said Goethe, "as the most sublime and useful science as long as they are applied in their proper place; but I cannot commend the misuse of them in matters which do not belong to their sphere, and in which, noble science as they are, they seem to be mere nonsense, as if, forsooth, things only exist when they can be mathematically demonstrated! It would be foolish for a man not to believe in his mistress's love because she could not prove it to him mathematically. She can mathematically prove her dowry, but not her love." Some scientists in our day are insisting that every thing, even in history, morals, and religion, is to be settled by experiment and calculation, and would place all truth under the microscope—subject it to the blowpipe, and express it in statistics—and they do not see that the highest truth escapes in the process. The defenders of religion maintain that in religion a sincere mind will discover the truth with or without scientific knowledge. Many believe that John Bunyan saw as far into spiritual matters as even Newton or Locke, and much farther than Laplace ever did. Some of the highest statesmen and lawyers in Great Britain imagined that they could get more good from the direct and homely appeals of Moody than from those select *dilettant* meetings in London of *savants* and *littérateurs* who have abandoned Christianity, and are seeking to catch some higher religion which evanishes as they would lay hold of it.

Everybody acknowledges that all witnesses are not to be trusted; yet in the common affairs of life, in trials, in history, we do find testimony which we implicitly believe. To the great body even of educated men, scientific knowledge depends on the trustworthiness of those who have made the observations and experiments. Notwithstanding all their preconceptions, there are declarations of men of science as to matters of fact which we can trust; and it would be a violation of their whole nature, in fact it would be a miracle, were they to deceive us. Dr. Carpenter is entitled to credit for having helped to expose the fooleries and the rogueries of spirit-rapping, rope-tying, and of levitation. But he seems to think that it is possible by the same method to undermine the miracles of the Old and New Testaments. All who have inquired carefully into the subject see that the testimony in favor of spiritualistic manifestations cannot stand the common tests of evidence. But it has been maintained by many of the greatest and most sagacious minds, and by the highest moral minds which our world has produced, that the testimony in behalf of the essential events of the New Testament cannot be set aside without undermining the whole of ancient history. Even at first sight the spiritual *séances* and performers have no moral prestige in their favor. The products are unworthy of God, and inconsistent with his mode of operation in Nature. We can discover motives enough to induce them to act as they do—such as the desire to create wonder—with some the hope of getting money. How different with our Lord, who, so far from taking advantage of the wonder-loving spirit of the Jews, actually restrained it! The wonders of the spiritualists are performed in rooms prepared for the purpose or in darkness, whereas the miracles of our Lord were performed in open day, in unexpected circumstances, and before all men. Then the whole teaching of Jesus was totally above and altogether opposed to the spirit of his age and nation, and only exposed him and his followers to opprobrium, poverty, and suffering.

But Dr. Carpenter has discovered that there is no stronger evidence in behalf of the events of our Lord's life than we have in favor of the miracles attributed to St. Columba. This is a proof that, amid his multifarious employments, Dr. Carpenter has not carefully surveyed or minutely examined the whole body of Christian evidences. The only original life of Columba is the "Vita" of Abbot Adamnan, written about one hundred years after the saint's death. All that it proves is, that at the time the life was written Columba was believed to have wrought miracles. But there is satisfactory proof that the first gospels were written while many who had seen the events were still alive. The account given by the abbot was all in accordance with the popular belief, and had not, like the earlier Christian records, to encounter the hostile criticism of keen and able opponents. The voice of the Irish dove was a very pleasant one, but all the good words uttered were got from him on whom the spirit alighted as a dove. We have no utterances of his to be compared with the teachings of our Lord and his disciples. Then we have no record of such lives and sacrifices as are described in the letter of Pliny the Younger in A. D. 112. Nor have we such corroborations as the Book of Acts, such original productions as the Epistles of Paul, such a mighty result as Christianity with its influence over the world, over its education and its civilization, for the last eighteen hundred years.

Dr. Carpenter quotes Locke as saying that we are to regard the doctrine as proving the miracle rather than the miracle proving the doctrine. Locke believed both the doctrine and the miracle. Dr. Carpenter does not tell us whether he believes either. He does not say whether he looks on the doctrine as proving the miracle. The wisest defenders of Christianity have always combined the two, the lofty teaching and the high morality, with the attested supernatural action. In estimating the validity of even common testimony we combine the character of the witness with the facts to which he depones. We look to his manner of testifying, to the consistency and transparency of his statements, even to the name he has borne among his associates and the motives by which he may have been swayed. So in weighing the evidence we have for Christianity we are entitled to combine the truth testified to with the testimony. We do not choose to separate the record of miracles in Matthew from the Sermon on the Mount. We are prepared to believe that he who uttered those bold and transparently sincere and pure precepts could not have been guilty of deceit. It is clear that Jesus claimed supernatural power. If there be any truth at all in the accounts of him, in fact, if there ever was such a person as Jesus, it is clear that he claimed to work miracles. His claims are found imbedded in the heart of discourses which contain his loftiest ideas, moral and spiritual, far beyond the conception of the evangelists or the early Christian writers. His discourses are, in fact, his greatest miracle. His acts and words are like the warp and woof of his garment, which is woven throughout and cannot be divided.

The doctrines, the precepts, the providential occurrences, the miracles, constitute a system quite as much as the Cosmos does. In this system one part supports another, each helps to bear up the whole, and the whole makes every part cohere. He who assails Christianity has to attack a phalanx. The pure morality fits in to the character of God, revealed as a spirit, revealed as light, revealed as love. The miracles, being almost all of them meant to remove evil, most of them to heal diseases, adapt themselves to the manifest disorder in the world, to our consciousness of sin, and the doctrine which reveals an atonement. The supernatural system is higher than the natural, but it is in accordance with it. The higher joins on beautifully to the lower quite as fittingly as vegetable life superinduces itself on inanimate Nature, as animal life completes vegetable life, as the soul fits into the body. Science and philosophy may not be able to go back to a beginning, but they require a source. It is not more certain that "*ex nihilo nihil fit*" than it is that what produces must have power to produce. All these later discussions as to force and cause show that there must be some intimate connection between the effect and its cause. Mayer wrought out the grand doctrine of the conservation of force by the principle that "cause equals effect." This is not, as it appears to me, the correct expression of the law, but it points to a deep law lying at the basis of that development which men are studying so eagerly in the present day. All that is in the effect has come from the causes—it may be the successive causes. We are thus carried back to an inherent power, not created by development, but the source or spring of development. This source may surely be declared supernatural. The Bible simply speaks of the continuance of that supernatural in revelation and in inspiration. This supernatural is not inconsistent with the natural; it is the complement of it. The higher world overarches the lower world as the sky does the earth. The world to come consummates what is begun in the present world—provides a place for the immortal soul, and for the body raised to join it.

The conclusion of the whole matter is, that we are to weigh the evidence in behalf of revelation in the same way as we weigh any other evidence, laying aside all "prepossessions" and "expectancies" for and against supernaturalism; and that the evidence for Christianity, so large, so varied, so compact, is not to be summarily set aside by any physiological doctrine sufficient to explain mesmerism and spirit-rapping.

# LESSONS IN ELECTRICITY.[1]

## HOLIDAY LECTURES AT THE ROYAL INSTITUTION.

By Prof. TYNDALL, F. R. S.

### II.

SECTION 8. *Electrics and Non-Electrics.*—For a long period, bodies were divided into *electrics* and *non-electrics*, the former deemed capable of being electrified, the latter not. Thus the amber of the ancients, and the spars, gems, fossils, stones, glasses, and resins, operated on by Dr. Gilbert, were electrics, while all the metals were non-electrics. We must now determine the true meaning of this distinction.

Take in succession a ball of brass, of wood coated with tin-foil, a lead bullet, and an apple, in the hand, and strike them briskly with silk, flannel, or the fox's brush; none of them will attract the balanced lath (Fig. 4), or show any other symptom of electric excitement. All of them, therefore, would have been once called non-electrics.

But suspend them in succession by a string of silk held in the hand, and strike them again; every one of them will now attract the lath.

Reflect upon the meaning of this experiment. We have introduced an insulator—the silk string—between the hand and the body struck, and we find that by its introduction the non-electric has been converted into an electric.

The meaning is obvious. When held in the hand, though electricity was developed in each case by the friction, it passed immediately through the hand and body to the earth. This transfer being prevented by the silk, the electricity, once excited, is retained, and the attraction of the lath is the consequence.

In like manner, a brass tube, held in the hand and struck with a fox's brush, shows no attractive power; but when a stick of sealing-wax, ebonite, or gutta-percha, is thrust into the tube as a handle, the striking of the tube at once develops the power of attraction.

And now you see, more clearly than you did at first, the meaning of the experiment with the heated foolscap and India-rubber. Paper and wood always imbibe a certain amount of moisture from the air. When the rubber was passed over the cold paper, electricity was excited, but the paper, being rendered a conductor by its moisture, allowed the electricity to pass away.

Prove all things. Lay your cold foolscap on a cold board, supported by warm dry tumblers; pass your India-rubber over the paper; lift it by a loop of silk, for if you touch it it will discharge itself.

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[1] A course of six lectures, with simple experiments in frictional electricity, before juvenile audiences during the Christmas holidays.

You will find it electric; and with it you can charge your electroscope, or attract from a distance your balanced lath.

The human body was ranked among the non-electrics. Make plain to yourself the reason. Stand upon the floor and permit a friend to strike you briskly with the fox's brush. Present your knuckle to the balanced lath, you will find no attraction. Here, however, you stand upon the earth, so that even if electricity had been developed, there is nothing to hinder it from passing away.

But, place upon the ground four warm glass tumblers, and upon the tumblers a board. Stand upon the board, and present your knuckle to the lath. A single stroke of the fox's fur, if skillfully given, will produce attraction. If you stand upon a cake of resin, of ebonite, or upon a sheet of good India-rubber, the effect will be the same.

Throw a mackintosh over your shoulders, and let a friend strike it with the fox's brush, the attractive force is greatly augmented.

After brisk striking, present your knuckle to the knuckle of your friend. A spark will pass between you.

This experiment with the mackintosh further illustrates what you have already frequently observed, namely, that it is not friction alone, but the friction of special substances against each other, that produces electricity.

Thus we prove that non-electrics, like electrics, can be excited, the condition of success being, that an insulator shall be interposed between the non-electric and the earth. It is obvious that the old division into electrics and non-electrics really meant a division into insulators and conductors.

SEC. 9. *Discovery of Two Electricities.*—We have hitherto dealt almost exclusively with electric attractions, but, in an experiment already referred to, Otto von Guericke observed the *repulsion* of a feather by his sulphur globe. I also anticipated matters in the use of our Dutch gold electroscope, where the repulsion of the leaves informed us of the arrival of the electricity.

Du Fay, who was the real discoverer here, found a gold-leaf floating in the air to be at first attracted and then repelled by the same excited body. He proved that when it was repelled by rubbed glass, it was attracted by rubbed resin—and that when it was repelled by rubbed resin, it was attracted by rubbed glass. Hence the important announcement, by Du Fay, that there are two kinds of electricity.

The electricity excited on the glass was for a time called *vitreous* electricity—while that excited on the sealing-wax was called *resinous* electricity. These terms are, however, improper; because, by changing the rubber, we can obtain the electricity of sealing-wax upon glass, and the electricity of glass upon sealing-wax.

Roughen, for example, the surface of your glass tube, and rub it with flannel, the electricity of sealing-wax will be found upon the vitreous surface. Rub your sealing-wax with vulcanized India-rubber, the electricity of glass will be found upon the resinous surface.

We now use the term *positive* electricity to denote that developed on glass by the friction of silk; and *negative* electricity to denote that developed on sealing-wax by the friction of flannel. These terms are adopted purely for the sake of convenience. There is no reason in Nature why the resinous electricity should not be called positive, and the vitreous electricity negative. Once agreed, however, to apply the terms as here fixed, we must adhere to this agreement throughout.

SEC. 10. *Fundamental Law of Electric Action.*—In all the experiments which we have hitherto made, one of the substances has been electrified by friction, and the other not. But, once engaged in inquiries of this description, questions incessantly occur to the mind, the answering of which extends our knowledge, and suggests other questions. Suppose, instead of exciting only one of the bodies presented to each other, we were to excite both of them, what would occur? This is the question which was asked and answered by Du Fay, and which we must answer for ourselves.

Here your wire loop (Fig. 1), comes again into play. Place an unrubbed gutta-percha tube, or a stick of sealing-wax, in the loop, and be sure that it *is* unrubbed—that no electricity adheres to it from former experiments. If it fail to attract light bodies, it is unexcited; if it attract them, pass your hand over it several times, or, better still, pass it over or through the flame of a spirit-lamp or candle. This will remove every trace of electricity. Attract the unrubbed gutta-percha tube by a rubbed one.

Remove the unrubbed tube from the loop, and excite it with its flannel rubber. One end of the tube is held in your hand, and is therefore unexcited. Return the tube to the loop, keeping your eye upon the excited end. Bring a second rubbed tube near the excited end of the suspended one: strong repulsion is the consequence. Drive the suspended tube round and round by this force of repulsion.

Bring a rubbed glass tube near the excited end of the gutta-percha tube: strong attraction is the result.

Repeat this experiment step by step with two glass tubes. Prove that the rubbed glass tube attracts the unrubbed one. Remove the unrubbed tube from the loop, excite it by its rubber, return it to the loop, and establish the repulsion of glass by glass. Bring rubbed gutta-percha or sealing-wax near the rubbed glass: strong attraction is the consequence.

These experiments lead us directly to the fundamental law of electric action, which is this: Bodies charged with the same electricity repel each other, while bodies charged with opposite electricities attract each other. Positive repels positive, and attracts negative. Negative repels negative, and attracts positive.

Devise experiments which shall still further illustrate this fundamental law. Repeat, for example, Otto von Guericke's experiment. Hang a feather by a silk thread, and bring your rubbed glass tube near it: the feather is attracted, touches the rod, charges itself with the electricity of the rod, and is then repelled. Cause it to retreat from the rod in various directions.

Hang your feather by a common thread: if no insulating substance intervenes between the feather and the earth, you can get no repulsion. Why? you ought to be able to answer. Obviously it is because the charge of positive electricity communicated by the rod is not retained by the feather, but passes away to the earth. Hence, you have not positive acting against positive at all. Why you should have the attraction of the neutral body by the electrified one will, as already stated, appear by-and-by.

Attract your straw needle by your rubbed glass rod. Let the straw strike the rod, so that the one shall rub against the other. The straw accepts the electricity of the rod, and repulsion immediately follows attraction, as shown in Fig. 7.

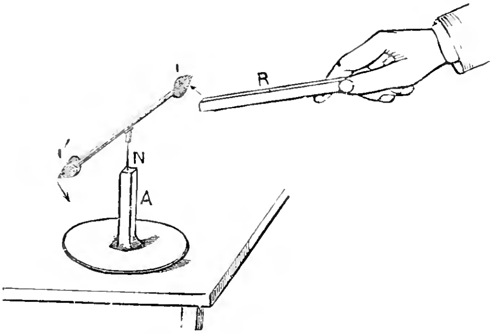

Fig. 7.

Mr. Cottrell has devised the simple electroscope represented in Fig. 8 to show repulsion. *A* is a stem of sealing-wax, with a small circle of tin, *T*, at the top. *W* is a bent wire proceeding from *T*, with a small disk attached to it by wax. *I I'* is a little straw index, supported by the needle, *N*, as shown in the figure. The stem, *A*, is not quite vertical, the object being to cause the bit of paper, *I*, to rest close to *W* when the apparatus is not electrified. When electricity is imparted to *T*, it flows through the wires, *W* and *w*, over both disk and index: immediate repulsion of the straw is the consequence.

No better experiment can be made to illustrate the self-repulsive character of electricity than the following one: Heat your square board again, and warm, as before, your sheet of foolscap. Spread the paper upon the board, and excite it by the friction of India-rubber. Cut from the sheet two long strips with your penknife. Hold the strips together at one end. Separate them from the board, and lift them into the air: they forcibly drive each other apart, producing a wide divergence.

Cut several strips, so as to form a kind of tassel. Hold them together at one end. Separate them from the board, and lift them into the air: they are driven asunder by the self-repellent electricity, presenting an appearance which may remind you of the hair of Medusa. The effect is represented in Fig. 9.

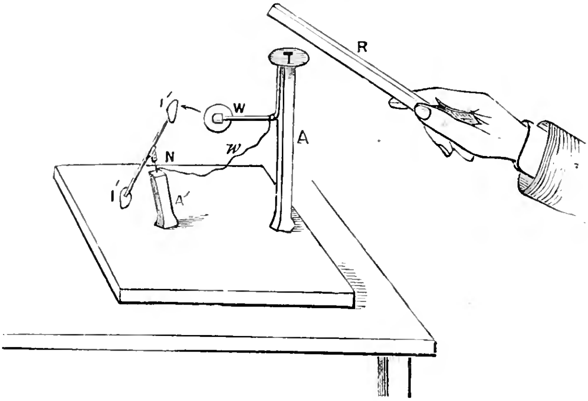

Fig. 8.

And now you must learn to determine with certainty the quality of the electricity with which any body presented to you may be charged. You see immediately that attraction is no sure test, because unelectrified bodies are attracted. Further on you will be able to grapple with another possible source of error in the employment of attraction.

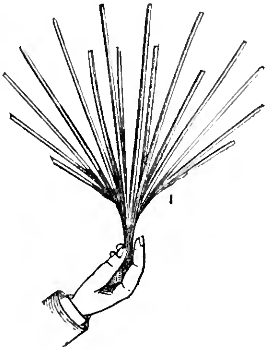

Fig. 9.

In determining quality, you must ascertain, by trial, the kind of electricity by which the charged body is repelled; if, for example, any electrified body repel, or is repelled by, sealing-wax rubbed with flannel, the electricity of the body is negative; if it repel, or is repelled by, glass, rubbed with silk, its electricity is positive. Du Fay had the sagacity to propose this mode of testing quality.

Apply this test to the strips of foolscap paper excited by the India-rubber. Bring a rubbed gutta-percha tube near the electrified strips, you have strong attraction. Bring a rubbed glass tube between the strips, you have strong repulsion and augmented divergence. Hence, the electricity, being repelled by the positive glass, is itself positive.

SEC. 11. *Double or "Polar" Character of the Electric Force.*—We have examined the action of each kind of electricity upon itself, and upon the other kind; but hitherto we have kept the rubber out of view. One of the questions which inevitably occur to the inquiring scientific mind would be, How is the rubber affected by the act of friction? Here, as elsewhere, you must examine the subject for yourself, and base your conclusions on the facts you establish.

Test your rubber, then, by your balanced lath. The lath is attracted by the flannel, which has rubbed against gutta-percha; and it is attracted by the silk, which has rubbed against glass.

Regarding the quality of the electricity of the flannel or of the silk, the attraction of the lath teaches you nothing. But, suspend your rubbed glass tube, and bring the flannel rubber near it: repulsion follows. The silk rubber, on the contrary, attracts the glass tube. Suspend your rubbed gutta-percha tube, and bring the silk rubber near it: repulsion follows. The flannel, on the contrary, attracts the tube.

The conclusion is obvious: the electricity of the flannel is positive, that of the silk is negative.

But the flannel is the rubber of the gutta-percha, whose electricity is negative; and the silk is the rubber of the glass, whose electricity is positive. Consequently, we have not only proved the rubber to be electrified by the friction, but also proved the electricity of the rubber to be opposite in quality to that of the body rubbed.

SEC. 12. *What is Electricity?*—Thus far we have proceeded from fact to fact, acquiring knowledge of a very valuable kind. But facts alone cannot satisfy us. We seek a knowledge of the *principles* which lie behind the facts, and which are to be discerned by the mind alone. Thus, having spoken, as we have done, of electricity passing hither and thither, and of its being prevented from passing, hardly any thoughtful boy or girl can avoid asking, What is it that thus passes?—what *is* electricity? Boyle and Newton betrayed their need of an answer to this question when the one imagined his unctuous threads issuing from and returning to the electrified body, and when the other imagined that an elastic fluid existed which penetrated his rubbed glass.

When I say "imagined" I do not intend to represent the notions of these great men as vain fancies. Without imagination we can do nothing here. By imagination I mean the power of picturing mentally things which have an existence as real as that of the world around us, but which cannot be touched directly by the gross bodily organs of sense. I mean the purified scientific imagination, without the exercise of which we cannot take a single step into the region of causes and principles.

It was by the exercise of the scientific imagination that Franklin devised the theory of a single electric fluid to explain electrical phenomena. This fluid he supposed to be self-repulsive, and diffused in definite quantities through all bodies. He supposed that when a body has more than its proper share it is positively, when less than its proper share it is negatively, electrified. It was by the exercise of the same faculty that Symmer devised the theory of two electric fluids, each self-repulsive, but both mutually attractive.

At first sight Franklin's theory seems by far the simpler of the two. But its simplicity is only apparent. For, though Franklin assumed only one fluid, he was obliged to assume three distinct actions. Two of these were the mutual repulsion of the electric particles among themselves, and the mutual attraction of the electric particles and the ponderable particles of the body through which the electricity is diffused. These two assumptions, moreover, when strictly followed out, lead to the unavoidable conclusion that the material particles must also mutually repel each other. Thus the theory is by no means so simple as it appears.

The theory of Symmer, though at first sight the most complicated, is in reality by far the simpler of the two. According to it electrical actions are produced by two fluids, each self-repulsive, but both mutually attractive. These fluids cling to the atoms of matter, and carry the matter to which they cling along with them. Every body, in its natural condition, possesses both fluids in equal quantities. As long as the fluids are mixed together they neutralize each other, the body in which they are thus mixed being in its natural or unelectrical condition.

By friction (and by various other means) these two fluids may be torn asunder, the one clinging by preference to the rubber, the other to the body rubbed.

According to this theory there must always be attraction between the rubber and the body rubbed, because, as we have proved, they are oppositely electrified. This is in fact the case. And mark what I now say. Over and above the common friction, this electrical attraction has to be overcome whenever we rub glass with silk, or sealing-wax with flannel.

You are too young to fully grasp this subject yet; and indeed it would lead us too far away to enter fully into it. But I will throw out for future reflection the remark that the overcoming of the ordinary friction produces heat then and there upon the surfaces rubbed, while the force expended in overcoming the electric attraction may be converted into a spark which shall appear a thousand miles away from the place where it was generated.

Theoretic conceptions are incessantly checked and corrected by the advance of knowledge, and this theory of electric fluids is doubted by many eminent scientific men. It will, at all events, have to be translated into a form which shall connect it with heat and light, before it can be accepted as complete. Nevertheless, keeping ourselves unpledged to the theory, we shall find it of exceeding service both in unraveling and in connecting together electrical phenomena.

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# RECENT GEOGRAPHICAL PROGRESS.[1]

By Chief-Justice DALY,

PRESIDENT OF THE GEOGRAPHICAL SOCIETY.

THE year 1875 completed the third quarter of the nineteenth century, a period distinguished by the activity which has prevailed in every branch of scientific inquiry, but particularly distinguished as a remarkable period of geographical exploration and discovery.

The history of geographical knowledge is a history of its rapid acquisition in periods very limited in point of time, but of great activity, and of long intervals of repose, in which comparatively little was done, or a great deal lost that had been previously acquired. For the last twenty-five years we have been living in one of those periods of exceptional activity, for at no time has an interest so wide-spread been manifested for geographical exploration since that great age of maritime discovery, that began in the early part of the fifteenth century with the exploration of the western coast of Africa by the Portuguese, and culminated in the circumnavigation of the globe by Magellan. The comparatively small limits of about a century is all that is embraced from the time (1418), when Prince Henry of Portugal, surnamed the Navigator, took up his abode upon the promontory of Sagres to devote the residue of his life to the fitting out of expeditions for the exploration of the coast of Africa beyond Cape Bojàdor, a region then wholly unknown, and the year 1519, when Magellan entered the Pacific by the discovery of the straits that bear his name. Within that period the captains of Prince Henry had sailed around the continent of Africa; Columbus had discovered America; his companion, Nuñez de Balboa, the Pacific; Sebastian Cabot had followed

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[1] From advance-sheets (introductory portion) of the President's annual address before the American Geographical Society, on "The Geographical Work of the World in 1875."

the coast of North America to the sixty-seventh parallel of north latitude; and Magellan's vessel the Vittoria, after sailing around the world, had returned in 1522 to San Lucar, in Spain, the port whence she set out.

The century that followed this period of discovery was occupied with the more particular exploration and settlement of the regions thus brought to the knowledge of mankind, and with the labors of geographers and cartographers in arranging the great mass of new materials into a reconstructed system of geography. With the exception of fruitless efforts to discover, in the interest of commerce, a northeast or a northwest passage to the Indies around the northern part of the globe, or directly across the pole, the zeal for geographical discovery abated through the seventeenth and eighteenth centuries; the world being sufficiently occupied with what it had already acquired, either in building up great empires in the newly-discovered continents of North and South America, or by extending the rule of maritime nations over the coast of Africa, and the remoter parts of Asia, as in the settlement of the colonies established by the Portuguese, and by the British conquest of India. In fact, so large a portion of the earth's surface had become known within so short a period, that it presented enough to absorb all the activity of civilized nations for three centuries in the work of colonization, settlement, or conquest.

It was not until near the middle of the nineteenth century when this great work had produced its results in the establishment of such nations as the United States, Mexico, the republics of Central America, Brazil, the other states of South America, and of a vast dominion under British rule in India, and by the extension of Russia over a large part of Northern Asia, that the attention of mankind was again drawn to the yet undiscovered or imperfectly known portions of the earth, and a new interest awakened in geographical exploration and discovery. This may be said to have begun with the founding of a Geographical Society in Paris, in 1821; of another in Berlin, in 1828, and the establishment of the Royal Geographical Society of London, in 1830. These societies were formed to cultivate the science of geography in a more comprehensive spirit, to facilitate the acquisition of geographical information by the establishment of libraries, to disseminate it by publications, and to encourage and assist scientific travelers and explorers. Like all new things, however, it was some years before these societies produced any effect, or the world recognized the value of the purpose for which they were established; whereas the results which have since been brought about, chiefly through the instrumentality of such institutions, are beyond anything which the most sanguine of their projectors could have anticipated.

The Royal Geographical Society of London may be taken as an illustration of these societies. It has now 3,035 fellows, each paying

£2 a year, a large permanent capital, and an annual income of $35,000. It has a building of its own, a fine library and map room, and is able to send, and has frequently sent out expeditions for geographical exploration and discovery, sometimes in coöperation with the government, and sometimes without it. Before, however, it reached this state it had, as I have been informed, to struggle for some years, as we have had, to keep up its organization. The turning-point of its history, and in its influence, appears to have been the election, in 1843, of Sir Roderick I. Murchison to the presidency, then in the fullness of his fame as a geologist, but who thenceforth entered upon a new field, and one by which he was afterward chiefly known. In his first annual address, an elaborate and exhaustive production, he surveyed the then state of geographical research throughout the world, and pointed out with remarkable sagacity that the parts of the globe to which exploration and research should be directed and concentrated were central Africa, Australia, and the regions surrounding the north and south poles. Although his own fame had been made as a geologist, his course then and during the many years that he was the guiding spirit of the Royal Geographical Society showed very plainly his conviction that a thorough knowledge of the surface of our own planet, and of those physical laws that affect everything upon it, is practically of more importance to us than a knowledge of its past physical history or of other bodies in space.

It was not that he undervalued the sciences of geology and astronomy, which, in fact, form a part of the science of geography; but the earth is our own planet, the details of which are within our grasp, and there is therefore the greater reason why every effort should be directed to acquire a thorough knowledge of it, particularly as the increase of that knowledge requires widely-extended efforts over different parts of it, and a vast accumulation of details. I am not now expressing anything he may have said, but rather deducing my own conclusions of what he thought from what he did. He was evidently impressed with the conviction that sufficient attention was not then given to the advancement of the science of geography, and to his eminently practical mind it was clear that it was not to be advanced by simply studying it in the closet, but by explorations and scientific researches, requiring persistent efforts, continuous expenditures, and the labors of a numerous, zealous, and intelligent class of workers over a large part of the earth's surface. To accomplish this, the whole age had to be influenced, governments enlisted, and the different societies brought into active coöperation with each other, and it was to this work that Sir Roderick then set himself, and to which he may be said to have chiefly devoted the remainder of his life.

I have selected Sir Roderick Murchison rather as a type, for it was not to him alone, but to many other eminent men in France, Germany, Russia, Italy, and other countries, preëminent among whom was Alexander von Humboldt, that the conviction became general that the unknown, or imperfectly known, parts of the earth should be thoroughly investigated, and scientific researches actively prosecuted in respect to all phenomena coming under the general head of physical geography. This has, in fact, brought about, as I have said, a geographical age. There are now scattered over the globe thirty-four geographical societies, and, if we add other organizations devoted in part to geographical inquiry or labors, the number would be augmented to about fifty. Many of them are well endowed, large in point of numbers, and strengthened not only by the coöperation of, but by annual grants of money from, the governments of the countries in which they are situated.

How thoroughly this spirit was aroused, will appear by a brief, but necessarily imperfect, statement of what has been accomplished since this movement began.

When it commenced, the map of Africa was, with the exception of the northwestern projection, above the Gulf of Guinea, and the Nile region, almost a blank from the Mediterranean to the country in the vicinity of the Cape of Good Hope. Of the 17,000,000 of square miles in Asia, about 12,000,000 were either entirely unknown, or wholly cut off from all intercourse with mankind. The condition of Australia, with an area of 3,000,000 of square miles, is best expressed by quoting the language of a geographer of that day. "A corner of this huge mass of land," he says, "is all that is known." Twenty-five years ago the European population of Australia was estimated at about 50,000; it is now over 1,500,000, or thirty times as great.

The second island in point of size, and one of the most fruitful in the world, Papua, or New Guinea, is referred to by the same geographer Murray, as almost a *terra incognita*, having generally, he then said, "been viewed only by navigators from a distance;" and in respect to the next great island, Borneo, he puts the population of the colonies there under the Dutch at about 9,000. In 1870 the population of the Dutch colonies in Borneo was 189,253. The settled portion of the United States then embraced 800,000 square miles, beyond which was an area of 2,500,000 square miles inhabited by savages, and almost unknown; for we knew little of it then beyond what was known in the time of Jefferson, with the exception of Major Long's journey and Prof. Nicollet's exploration of the head-waters of the Mississippi.

This was the state of things at the beginning of the period referred to. I will now enumerate what has been done since, and especially within the last twenty-five years.

In *Asia:* the opening of the whole of China and Japan; the acquisition by the Russians of nearly the whole of Toorkistan, and the inauguration of a policy on their part which, either by treaty or military conquest, will throw open the whole of Northern Asia to the free intercourse of the world. The extensive explorations by them in Northern Siberia, and of the rivers that flow into the Arctic. The many journeys, explorations, geographical and archæological, made through Southern Arabia, Persia, Afghanistan, Beloochistan, and the northern regions of India, and explorations of the like character in Burmah, Siam, and Cambodia. The settlement of the French in Cochin-China, and journeys to a partial extent in Corea, and to a greater extent in Mantchooria. The Euphrates Expedition. The continuation of the great survey of India. The survey of Palestine, and the cutting of the Suez Canal.

In *Africa:* the discovery of the great lakes, as well those which are the reservoirs of the Nile, as those lying south of the equator. The exploration of the country south of Abyssinia, between these lakes and the eastern coast, and the discovery of the great range of mountains in that region, with their snow-capped peaks, the most elevated land in Africa. The military occupation of Abyssinia and of Ashantee by the English; the extensive journeys and researches in Northern and Northeastern Africa, by Barth, Overweg, Richardson, Rohlfs, Schweinfurth, Miani, Nachtigal, and others. The various expeditions and individual journeys along the western coast, and the explorations of its immediate interior by Du Chaillu, Burton, Baines, Blyden, Gandy, Güssfeldt, etc., etc. The two journeys across Central Africa, from east to west, and west to east, by Dr. Livingstone; his journey from the Cape upward; his exploration of the Zambezi, and of the countries by which it is watered; his discovery of the great network of rivers and lakes in Central Africa, below the equator, which he was pursuing at the time of his death, and the following up of that exploration by Lieutenant Cameron, with the latter's journey through Central Africa, from east to west. The numerous explorations in South and Southeastern Africa, from the Orange River to the Limpopo, and from that point along the eastern coast and its interior, as far as the parallel of Zanzibar, which, with the exploration of the imperfectly known parts of the Island of Madagascar by Grandidier and Mullins, is but a very general statement of what has been done in Africa. What exploration has accomplished in Africa may be judged by a single fact. In 1850 the area of cultivated land in Egypt was 2,000,000 of acres; in 1874 it was 5,000,000.

I may next refer to the numerous explorations around and across the great continent of Australia from Sturt's early journey to the last ones of Warburton and Forster. The survey of large portions of the coast of Papua or New Guinea, and explorations in the interior by Beccaria, D'Albertis, Meyer, Van Rosenberg, and MacLeay. The explorations in Formosa by Steere, Le Gendre, and others, and the settlement of colonies and the establishment of governments by the English in New Zealand and the Feejee Islands. The explorations of the Arctic to within sight of the eighty-third parallel of north latitude, including the discovery of the long-sought northwestern passage, and of its inutility. The exploration of the antarctic circle as far as the 73° of south latitude, and the remarkable discovery that the ice-bound regions, both of the Arctic and Antarctic, were, at a former period of the world's history, covered with a luxuriant vegetation, and that plants and animals then existed there in great abundance, which are found now only in the tropics, or in the more southern parts of the temperate zone.

And finally our own explorations of the great Western region, between the Mississippi and the Pacific, by Fremont, Emory, Simpson, Marcy, Stansbury, Sitgreaves, Gunnison, Beckwith, Whipple, Williamson, Parke, Warren, Ives, Reynolds, Macomb, Mullen, Wheeler, and other gallant, efficient, and distinguished military officers conducting reconnoissances or expeditions across its plains, deserts, and mountains, accompanied in these expeditions by scientific civilians, to whose labors we are indebted for our knowledge of its geology, agricultural resources, and natural history. Among strictly scientific works by civilians I should also enumerate Whitney's survey of California, followed by King and Gardner's belt of geological and topographical survey across the North American Cordilleras, Hayden and Gardner's survey in the Rocky Mountains, and Powell and Thompson's of the great cañons of the Colorado, through whose united labors so much of the geography of this vast region has become known; its great mountain-ranges, extraordinary cañons, wonderful geysers, deeply interesting ruins of a prehistoric and semi-civilized people of whom we know but little; its lakes, rivers, majestic cataracts, broad areas of cultivable land, already largely and to be still more extensively settled, and finally the millions it has yielded in gold and silver; a region so vast beyond the one hundredth meridian, that it will be twenty years before we obtain proper maps of it, unless the Government is more liberal in providing for its exploration and survey than it has hitherto been.

To these geographical labors and explorations within this period in various parts of the globe must also be added extensive researches of a geographical character, such as deep-sea dredgings, for the investigation of the temperature of the ocean, the movements of submerged currents, the plant and animal life existing at great depths, and the configuration of the bottom of the seas. The observation and study of oceanic currents and their cause. The distribution of heat north and south of the equator by the instrumentality of these currents, and its effects upon climate, as well as the effect of the currents from polar regions in modifying the heat of the equator. The meteorological observations in respect to the course of the winds; and the investigations of the laws and of the cause of hurricanes, cyclones, and other aërial disturbances. The magnetic observations in elucidation of the difficult subject of terrestrial magnetism. The numerous measurements of great mountain-heights in the more elevated regions of the globe. The extensive survey of coasts, prominent among which is our own great Coast Survey. The trigonometrical surveys carried on in many countries in Europe. The investigation of the cause of the glacial epoch, and possibly of inter-glacial epochs, or a succession of alternate warm and cold periods, each extending over long epochs of time, and their effect in bringing about the present condition of the earth's surface by changes in the level of the sea and the submergence of the land.

This very inadequate statement will show how great, wide-spread, and constant has been the work of exploration and research within the period referred to, and how truly it may be denominated a geographical age.

## THE MOLLUSKS OF THE ROCKY MOUNTAINS.

By ERNEST INGERSOLL.

IN the summer of 1874 it was my privilege to accompany one of the parties of the United States Geological Survey of the Territories, of which Dr. F. V. Hayden is chief. The field of operations was the mountainous region of Southern Colorado, and it afforded a good opportunity to examine the natural history of the region traversed.

The mammals of the Rocky Mountains have long been well known, particularly the large game, which, except in the distant portions of the Territory of Colorado, has been greatly depleted by the constant pursuit of hunters and trappers. The case is somewhat the same with the game-birds; while the enthusiastic labors of Henshaw, Aiken, Allen, Coues, and other ornithologists, have given us a very complete knowledge of all the birds and their habitats. The fishes and reptiles have received some attention too; and, in the lower, invertebrate forms of life, the investigations of Thomas upon the grasshoppers, Carpenter on the butterflies and moths, and Edwards, Packard, and Hagen on other insects, and the reports upon crustacea and worms by Verrill, Smith, Leidy and others, have given us a tolerable knowledge of the extent to which those forms are to be found in that region. But the mollusks of the mountains—land-snails, pond-snails, river-snails, and fresh-water mussels—have been almost entirely neglected, except by Dr. Cooper, in the north. From Colorado only seven had been reported, which were collected by Lieutenant Carpenter. This, then, seemed to be the field most needing cultivation, and my attention was chiefly turned to it during three months of wandering over the mountain-ranges, parks, and sterile plains, that diversify the country between Middle Park and the corner of Arizona. Something was found at nearly every camp, and, when the collection was at home and counted, it was somewhat surprising to find over fifty species, only nine of which had been hitherto known to exist in the Central Province, where an extreme "paucity of species, . . . . owing to the nature of its climate and soil," had been alleged. Five of these species were new to science, and have since been described in the "Bulletin of the United States Geological Survey," second series, No. 2, which has since been reprinted in an extended and revised form, in the Annual Report of the Survey for 1874.

The Central Province alluded to above is the name given by Mr. W. G. Binney[1] to that portion of the United States embraced between the crests of the Sierra Nevada and Cascade Mountains on the west and the edge of the great plains on the east. It was considered to be unfavorable to the development of pulmonates and deficient in the number of species to be found, and that its fauna was closely allied to that of the Eastern States, whence it had been largely derived by way of the north, where the plains are succeeded by forests and the Rocky Mountains dwindle into hills.

With respect to this distribution of mollusks in Colorado, none were found on the eastern slope of the range, although there is no conclusive evidence that they do not exist there; altitude seemed to have very little influence upon their dispersion, as long as other favorable conditions were present, and some species had a very local distribution.

The eastern slope of the Snowy Range is abrupt, and receives comparatively little rain. Westward of the summit, however, certain genera—as *Zonites*, *Vitrina*, *Vallonia*, *Patula*, *Pupa*, *Succinea*, and *Pisidium*—were everywhere represented. Vitrinas and pupas were, perhaps, the most common forms, the latter being particularly numerous on the Sierras in the southeastern corner of the Territory, where *Pupilla alticola* were traced up to the very limit of timber-growth, and upon the face of precipitous cliffs of volcanic rock, in whose clefts only tufts of grass could gain a foothold. With the latter shell also occurred some small succineas, and a mollusk with a delicate, box-shaped shell, only one-tenth of an inch in diameter. Plenty of these little fellows, as lively as could be, were to be found at the astonishing height of 11,500 feet. They proved to be undescribed, and to belong to the sub-genus *Microphysa*, the two American species of which, heretofore known, are natives of the Gulf coast and the West Indies. Why this species should depart so far from the habits of its congeners as to thrive best in the arctic climate of these mountain-tops, is strange. This *Microphysa* was afterward met with in the valleys south of these Sierras, and in the mountains west of North Park. In this same southern group of mountains many other shells were found—at a lesser altitude, but where water froze every night in August—of the same species as existed in other parts of the Territory,

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[1] In the "Bulletin of the Museum of Comparative Zoölogy" (Cambridge, Mass.), vol. iii., No. 9, "Geographical Distribution of North American Mollusca."

and, indeed, all over the Central Province. The finding of *Pupilla Blandi*, heretofore known only as a fossil in Missouri River drift, living and abundant, is an instance worthy of special mention.

It would seem, then, that a range of high mountains, or any number of ranges, would not offer a serious obstacle to the migration of land mollusks, or an insurmountable one to fresh-water forms. The widespread dissemination of such slow-moving creatures is a curious argument for the length of time that the country must have remained in substantially its present condition.

The Sierras of which I have spoken are those which encircle Baker's Park and the San Juan mining region, and extend westward to the base of the great Uncompahgre Mountains, which trend northward not far from the Utah line. This group of volcanic and quartzite peaks constitutes the highest land anywhere in that region, and gives source both to the Rio Grande del Norte and to the head-waters of the Great Colorado River. Its steep southern sides are gashed with tremendous gulches through which the Rio las Animas, the Rio La Plata, the Rio los Mancos, and other streams, which go to make up the Rio San Juan, flow out into the terrible cañon-cut deserts that stretch away across Arizona to the Gila River. For a few miles after emerging from their rocky gates, these rivers water beautiful and fertile valleys, which are cut through the sandstones upturned against the intruded peaks, and which abound in springs. In these valleys are plenty of timber and undergrowth, the climate is rarely cold enough for snow even in winter, and there I expected to gather a rich conchological harvest. In this I was not disappointed, only regretting that I could not make a more thorough examination than was permitted by the rapidity of our travel. Between the Animas and La Plata the trail passes through a valley between the lowest of the foot-hills, where there is a pond of several acres extent, resorted to by all sorts of wild-fowl, inhabited by many forms of amphibious life, and choked with an exuberant aquatic vegetation. Here were found thousands of limneas of several species, and quantities of the common *Planorbis trivolvis* showing a large range of variation among themselves. Like the limneas, the planorbs were extremely fragile in texture, which may be owing partly to the soft bottom, and partly to the scarcity of lime in the water; and they were distinguished by a short vertical diameter, which peculiarity, also, may have been acquired by them from the necessities of their habitat, since snails having shells with small breadth of beam could most advantageously pass between the stalks of standing water-plants that everywhere crowded the pond. But the astonishing fact about this pond was, that on the shore were found perfect specimens—although dead—of the marine genus *Truncatella*, a broken specimen of an *Arca*, and living crabs pronounced by Prof. Sidney I. Smith, of New Haven, to be true salt-water forms belonging to the family *Astacidæ*. That these are survivors of the period, probably comparatively recent, when here was a soft-water marsh that remained caught in this basin among the hills after the country, for a long distance south of it, had become dry land, seems very evident. It is difficult otherwise to account for their presence.

Farther on, in the valley of the Rio La Plata, where it emerges from its magnificent quartz cañon, and where the gold placer-mines and prospective city of La Plata are situated, a fine collecting-ground was found. This was so far south that many deciduous trees grew in the river-bottoms, and nearly every terrestrial species hitherto met with was there to be had in plenty. For the next ten days we were entirely in the lava-blasted, treeless and waterless deserts on the northern margin of the Rio San Juan, engaged in exploring the vestiges of that ancient semi-civilized race of village Indians, the remnants of which still exist in the small tribe of Moquis on the Little Colorado. During this time no mollusks were found except, where there was a little moisture, a few pupas, which seem able to live anywhere, and many bleached shells of various species that had been drifted down from the mountains at times of high water.

Our return-journey from the San Juan country was made from its very sources along the course of the Rio Grande. It led us through Antelope Park, on the eastern side of which lies St. Mary's Lake, a beautiful little sheet of crystal water studded with islands, and held among precipitous cliffs that afford it no visible outlet. It seems to be merely a great rocky basin, holding the melted snows of the surrounding heights. Its surface is over 9,000 feet above the sea. There existed in countless numbers in this lake a large species of coil-shell which was a nondescript, and which I have since named *Helisoma plexata*. Each of the hundreds of individuals seen possessed in a more or less marked degree a twisted appearance, resulting from a change in the plane of revolution in old age, which is the most striking specific character. This sudden change in the directness of the growth causes the carina of the third whorl to rise into a sharp shoulder on the right side, while on the opposite side the third whorl sinks underneath the overflowing outer whorl. A similar change often occurs in the fourth whorl, giving a braided look to the shell. How this species came almost alone to inhabit this secluded lake is a problem, complicated by the fact that probably there is not another large *Planorbis* within fifty miles. That the wild-fowls, abundant on the lake, brought the eggs clinging to their feet, may be a plausible explanation; but where did they bring them from, and when? The bottom of the lake is, for the most part, rough conglomerate rock, and is in many places filled with tangled water-plants, which may partially account for the peculiarities of the species. The shells of this genus appear to be especially subject to distortion under abnormal conditions.

Continuing our course down the valley of the Rio Grande to the town of Del Norte, we there left the river and struck across the San

Luis Valley to Mosca Pass through the Sangre de Cristo Range. This alkali and sage-brush plain, fifty miles wide, is very far from being "the garden of the world," as it has been styled. Near the eastern side is a group of lakes, the water of which is highly alkaline. These lakes are the abode and breeding-place of wild geese and ducks in the greatest number, which are tormented without end by the gulls that also make the lakes their home. On the gravelly beaches I picked up many shells, and doubtless in the deep water many more species might have been dredged, had there been time. But nowhere were there any bivalves, except the little cyclades. The fact that there was no lack of molluscan life in these intensely bitter waters was not surprising, since mollusks seem to flourish in mineral springs of both hot and cold water everywhere. We had seen before a fine illustration of this adaptation to peculiar conditions. The Grand River, which flows through Middle Park, contains no mollusks at all that I could discover; but at Hot Springs, in a little lagoon filled at high water, large, clear, *ampullacea*-like forms of the familiar *Physa heterostropha* were common. Close by, in the few yards of exposed outlet of the springs of hot sulphur-water from which the locality derives its name, there occurred in the greatest profusion a blackish, globose variety of the same species only one-fifth of an inch long. The temperature of this water was at some points as high as 100° Fahr. In the basin of a still hotter spring not ten feet away, whose waters were saturated with chlorides of sodium and magnesium, hundreds of still smaller *Physæ* were floating about in mats glued together by a tangle of confervoid vegetation and the depositions of the water. All these seemed to have lost their apices by erosion, "which is extremely liable to happen to shells living in water charged with alkaline salts other than lime." On the other hand, quite as small and black were the examples from the pure cold springs near Saguache, where there was seemingly nothing whatever to stunt their growth.

I was stimulated, by the results of my study of my own collection from Colorado, to gather all possible information about the mollusks of the Central Province generally, as it has been limited above. The bibliography was quite large, but the notes of locality and station very meagre. Tabulating the sum of the information open to me, and including my own summer's work, I found that 138 nominal species had been recorded as occurring in this inter-montanic region. Of these, 49 were also Californian species; 15 occurred also in the Eastern United States; 8 hailed from the Colorado Desert; 7 were found all over the continent, and 8 all over the world; and 3 belonged in the Eastern Province, west of the Alleghanies only. This left 47 nominal species, whese range, so far as yet known, is confined to the Central Province. Many of the specific names in this list, however, rest upon very insecure foundations, and will, no doubt, soon be reduced to synonyms. With respect to their vertical distribution, observations in the Rocky Mountains do not tally well with D'Orbigny's notes from the Andes, since out of 156 species discovered in South America, he found only 13 between the thirty-fourth and forty-fifth parallels of latitude—which corresponds to the district of north latitude considered here—and only 10 species were found above 5,000 feet. My list of the Rocky Mountain mollusca, on the contrary, shows that 55 species out of the 138 inhabit heights exceeding 5,000 feet, and 10 species have been found above 10,000 feet. These latter, however, are all recorded from mountains south of the thirty-ninth parallel; but it is safe to say that, where there is moisture, a goodly collection of mollusks can be made in the mountains of the Territories all the way up to the timber-line. This is probably true of all parts of the world.

In a recent paper on the hypsometric distribution of mollusca in Europe, communicated to the French Academy of Sciences at Paris, at their meeting on October 11, 1875, M. P. Fischer alludes to the great regularity with which plants thrive on mountains, each at a certain height. The terrestrial mollusca, being unprovided with means of locomotion enjoyed by birds and insects, and being, moreover, dependent upon vegetable life for food, could not fail to be discovered in the same way as plants, and this supposition he confirmed by observation. Each species extends to an altitude the limits of which it does not overstep. M. Fischer has verified this in the central Pyrenees as well as in the Alps, and divided the altitudes into five zones, comprised between 1,500 feet and 7,500 feet. Each zone is distinguished by the name of a species of *Helix*. Thus, in the Pyrenees, the first zone, ending at a height of 3,000 feet, is called that of *Helix carthusiana;* the second, ending at 3,600 feet, *Helix aspersa;* the third, terminating at 4,500 feet, *Helix limbata;* the fourth, limited at 6,000 feet, *Helix nemoralis;* and the fifth, ending at 7,500 feet, *Helix carascalensis*. In the Alps, at the same altitudes, the names of the zones are respectively *Helix carthusiana*, *obvoluta*, *Fontenelli*, *sylvatica*, and *glacialis*. A few individual mollusks will, indeed, climb as high as 9,000 feet, but they all stop at the limit of perpetual snow. Various genera of fluviatile mollusks do not ascend higher than 3,000 feet, a circumstance which the author considered of some importance to geologists, since it proves that in the quaternary beds the fossiliferous strata containing those genera, such as *Neritina*, *Paludina*, etc., were deposited at small altitudes. The Lake of Goube, about three hours' walk from Cauterets, 5,364 feet above the level of the sea, is thickly peopled with trout, frogs, and mollusks.

The results of this inquiry into the geographical distribution of mollusks in the mountainous West are meagre enough, but may be of some use in future investigations. Whether this central region is a true zoölogical province considered with reference to the mollusca, and what is the origin of its fauna, are hardly to be answered yet.

Enough seems to be known, however, to show that this inter-montanic region is not so deficient as has been supposed, either in the number of its species or in representatives of adjoining faunas. The impression that the Central Province is unfavorable to pulmonate growth also seems wrong, except in respect to the scarcity of lime in the soil, to which cause we may probably attribute the fact that the more minute forms are in large majority.

# CHARACTER AND WORK OF LIEBIG.[1]

BY J. L. W. THUDICHUM, M. D.

JUSTUS LIEBIG was born on the 12th of May, 1803, at Darmstadt, in the grand-duchy of Hesse. His father was what in this country (England) we should term a wholesale druggist and dry-salter, a trade which is in Germany designated by the name of materialist. There is no doubt that the opportunities which he had of collecting chemical reagents, and of witnessing the preparation of many products which were the objects of his father's trade, early excited in him that curiosity which soon became an insatiable thirst. It is related on creditable testimony that at the age of fourteen years he had performed all the experiments of which he could get knowledge from books, or for which within his means he could obtain the materials, and it is related by himself that about that time there was not a work in the library of the Grand-duke of Darmstadt on chemistry which he had not read. Looking at his early days by the light of that information, we cannot doubt that the anecdote ordinarily told of his having been a dull boy is a mere mistake. He was abstracted by other pursuits, and therefore, no doubt, neglected his school-work, but that he should have been less gifted than others cannot, under the circumstances, be believed. It is related by a credible person that in 1817, when he and his school-fellows were speaking to each other as to what pursuit they were to select, he said that he was going to be a chemist, whereupon the other boys laughed at him and told him he was a great fool, for a chemist was nothing. However, times have changed, and what at that time was considered as no pursuit is now an honored profession.

In the year 1818 he gave a distinct direction to that early bent of his mind, and he followed almost the only way which at that time existed in Germany for studying chemistry; he became an apprentice in an ordinary apothecary's establishment. An apothecary in Germany is a more scientific person than perhaps many would believe. He has had a thorough training, he has passed examinations, and he represents, therefore, the scientific side of chemistry, pharmacy, and

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[1] From the "Cantor Lectures" delivered before the Society of Arts.

the science of drugs in perfection. To such an apothecary, residing at Heppenheim, near Darmstadt, Liebig went, and remained there about ten months, but in that occupation as an apprentice his mind soon became wearied, he saw that he could not attain his object; and when, while continuing some of his early experiments on the fulminates, on one occasion he had the misfortune to produce a great explosion, this fact quickly terminated his apprenticeship, and he returned to Darmstadt. These explosions in the early days of great chemists are not uncommon. It is related in the case of Scheele that, when he was apprenticed to an apothecary, he once had a great explosion, in consequence of which his landlady expelled him from the house.

Liebig returned to his father's house in the year 1814, and read for six months in order to prepare himself for visiting the University of Bonn. He there listened to the lectures on theoretical chemistry of the well-known Prof. Kastner, and he also studied the other natural sciences and some languages, and, what is very characteristic of his great genius and perseverance, he formed a society among the students for the purpose of teaching one another, and for discussing subjects connected with chemistry and physics. Kastner being called to Erlangen, Liebig followed him there, and we are told that there he read all the new chemical publications, established another students' society for the same object as the first, and made many friends among the students, of whom several continued that friendship up to their death. Thus the celebrated poet, Count Platen, corresponded with him to the time of his death in 1830, and of this friendship we can see many congenial influences in the writings of Liebig, for there is no doubt that, in his "Familiar Letters on Chemistry," the language, although always prose, frequently rises to the highest beauty, such as can only be produced by a mind of a poetical turn. The same influence of the classical period of German literature you will also perceive for example in the writings of Humboldt, particularly in his "Views on Nature," which are therefore considered as examples of classical German diction. Liebig also made the acquaintance of Bischof, the botanist, and of Engelhard, later Professor of Chemistry at Nuremberg. He went in for the severe study of what at that time was called philosophy, that is, he listened to the lectures on metaphysics and philosophy in general, of the then great Schelling. Now, let me give you the words of Liebig on that period of his life. He says: "I myself studied for some time in a university where the greatest philosophers and metaphysicians of the century carried the studying youths away to admiration and imitation. Who could at that time resist the infection? I, too, have lived and participated in this period so rich in words and ideas, so poor in true knowledge and solid studies: it has robbed me of two precious years of my life. I cannot describe the terror and dismay which I felt when I awoke from this giddy dream to consciousness. How many most gifted and talented men have I seen perish in this vertigo, how many wails about life-objects completely missed have I been obliged to hear afterward!" Thus he spoke in his work on the study of the natural sciences, which was published at Brunswick in 1840.

Now, in order that you may be able to apprehend what this kind of philosophy was, and to understand more fully the position from which he had to emancipate himself, even at that early time of his life, I will quote to you a very few passages, and I will make them as short as possible, compatible with illustration, from one of Schelling's works, from the periodical for speculative physics—mark the term, "Speculative Physics." I will quote the following passage: "Nature strives in the dynamical sphere necessarily to absolute indifference, not by magnetism nor by electricity is represented the totality of the dynamical process, but only by the chemical process. With the third dimension of the product the two other dimensions are opposed. In Nature itself there is one and inseparate, what is separated for the purpose of speculation." That is almost enough, but I will give you another passage which will be more striking because of the contrary itself being known to you. Here he says of the composition of water: "Water contains just the same as iron, but in absolute indifference as yonder in relative indifference, carbon and nitrogen, and thus all true polarity of the earth is reduced to an original south and north which are fixed in the magnet." Now, in order that you may believe that he did not merely speak of an admixture or impurity of carbon or nitrogen, but that he meant to say that it was the essence of water, and that it was really composed of these two elements, and not of any other, he goes on to say: "The animal is in organic Nature the iron; the plant is the water, for Nature begins with the relative separation of the sexes, and then ends in this separation. The animal decomposes the iron, the plant decomposes the water. The female and the male sex of the plant is the carbon and the nitrogen of the water." These are two examples of the philosophy of Schelling, which was believed at that time to be the science by which Germany could be regenerated, by which the generation which had then only just recovered its independence would be put on a firm mental basis. The followers of this system were called to the court of Prussia, and there Hegel, the philosopher, continued in a similar manner to teach doctrines which nowadays seem to be but a *farrago* of nonsense. Hegel says, for example, on the chemical process: "If electricity was the broken magnetism, because the opposite poles are independent bodies upon which the positive and negative electricity is distributed, and if the point of indifference is the explosion of an indifferent light by itself, then is the chemical process, on the other hand, the totality of the shaping. We have two independent bodies which belong more to the one or the other extreme; to the metal on the one hand, or the sulphur on the other, which meet in an indifferent medium, and by abandoning their abstract one-sidedness in which they decompose the medium combine to a third body which is the totality and the neutrality of the opposites, the dynamical process in its highest perfection."

When a young man of seventeen or eighteen years of age is capable of freeing himself from the trammels of such a chimera termed philosophy, which had taken such a deep hold of a whole nation as to cause to flock to the university where it was taught the selected youth of the whole country, you may give him credit for great power of mind and for great independence of judgment. Do not forget that this development of the philosophy of Schelling and Hegel was a consequence of the latter part of the philosophy of Kant. Kant's philosophy was great as long as it was based on the exact sciences, upon physics, and upon mathematics, but when he left that basis and went into the speculative philosophy he gradually went away from that basis which had made his early philosophy so sound and so full of meaning for the perfection of the human understanding. On the other hand, when you come to a further development of the same philosophy, namely, that of Fichte, there the speculative part vanishes entirely into insignificance, because that which Fichte taught was not such kind of nonsense as that which I have read to you, but it was a kind of moral philosophy which spoke to the youth of Germany, and taught them this one great proposition, which every one of them ought to feel, and which is the first condition of self-consciousness in man, namely, "I am I;" this was the great teaching of Fichte, by which he brought home to men their own value and their own powers, which cannot be said was the result of the other philosophy from which I have quoted.

In 1822 Liebig, having emancipated himself from this kind of teaching, took the degree of Doctor of Philosophy at Erlangen, when he was nineteen years old. In the autumn of that year he returned to Darmstadt; his researches and endeavors then became known, and he attracted the attention of the Grand-duke Ludwig I., of Hesse-Darmstadt, who conferred upon him a state stipend, to enable him to continue his studies at Paris. To Paris, therefore, he went. Now let us for a moment consider what was then the condition of chemistry at Paris. Lavoisier, the great reformer, who had established what was then called the antiphlogistic chemistry, had thirty years before died on the scaffold; Guyton de Morveau, Fourcroy, and Berthollet, whom the first Napoleon called the *plus brave des Français*, because he gave him chlorate of potassium, by which he hoped to overcome the want of nitre for his gunpowder; the great Société d'Arcueil, which worked through the whole of the war-times zealously at science, and published its memoirs—all these men had passed away. But there remained their disciples in the persons of Proust, Chevreul, Vauquelin, Gay-Lussac, Thénard, and Dulong. Chevreul is the only one of these celebrated men who now lives, and he has lately published, in the

*Comptes Rendus*, a very remarkable paper on the changes which are produced in the power of thinking and observing by age. Fourcroy, the great animal chemist, who, in connection with Vauquelin, laid the foundation of that physiological chemistry on which the modern science is based; then Gay-Lussac, Thénard, and Dulong, men of the new science, who continued the work in a most glorious manner, which in this country had been carried to such a glorious issue by Humphry Davy—these men were at that time teaching at Paris, and at the laboratory which the liberality of the first Napoleon and his envy of English discoveries had established at *L'École Polytechnique.* They contiued to study and shape the new science which was destined to give to the modern science of chemistry precision.

Liebig then worked with Thénard, listened to Gay-Lussac's lectures, and he met there the young German chemists, Runge, well known by his many researches on tar, and the tar products; Mitscherlich, the discoverer of isomorphism and polymorphism; Gustav Rose, the representative of the perfection of analytical and inorganic chemistry. In 1823 he brought his first paper on the fulminates of silver and mercury before the Academy. And now, let me quote to you what he says of that event in the first work which he ever published. In the preface, which is a dedication to Alexander von Humboldt, he says that at the meeting of the Academy, on the 28th of July, 1823, he had read his paper, and was just engaged in packing up his apparatus and preparations, when a man, one of the members of the Academy, approached him, entered into conversation with him, and in an incredibly short space of time knew how to elicit from him all his hopes, schemes, and intentions. He did not dare to ask, either from shyness or from accident, who the gentleman was who spoke to him, and he disappeared again among the academicians. But he says: "From that day all the doors of society, and of all institutions, were open to me. I did not know until many years afterward to whom I owed this introduction and favor." It was to Humboldt, who had so well recommended him to the great French chemists that Gay-Lussac, who never took any pupil whatever into his laboratory, accepted him as his only pupil, and, more than that, joined with him in his continuation of those researches which at that early age he had brought to such perfection. This preface is beautiful in its conception and feeling, and has been printed in all the seven editions of the work which have since been published. If there were time this would, perhaps, be the place to show the wonderful influence which Humboldt has exercised upon the science of all countries; but I must pass over that subject, and continue the account of Liebig's life.

Through the recommendations of Humboldt and Gay-Lussac, both of which were addressed directly to the Grand-duke of Hesse-Darmstadt, Liebig was, at the age of twenty-one years, by the supreme will and absolute power of the grand-duke, appointed first Professor of

Chemistry in the University of Giessen. A new chair was established for him, and as a laboratory he received a room, as he expresses it, with four walls. Great was the opposition against this new professor; for what was chemistry? Chemistry was no science, nobody knew anything of chemistry, nobody would have it. Moreover, the appointment had not been made in the regular way, therefore the whole of the authorities of the university set themselves against it. The consequence was that the majority of that university persecuted that man for twenty-seven years; and, no matter what was his reputation, the amount of his work, or the importance of his position, for twenty-seven years this man could never once be made Rector of the University of Giessen. But where are the opposing influences now? History will not mention their names. Their ultramontane participators tried to decry the great man as an atheist and materialist, and by that means to remove from him the assistance of the state, and to diminish his chance of gaining a living. But he was too strong for all of them. In the year 1826 he was appointed Professor in Ordinary, a promotion by which he became a fixed servant of the state and a fixed member of the university. In that year he married Henrietta Moldenhauer, a most amiable lady, who now survives him.

Now comes the period of work which lasted to the year 1834. The work itself I will not now enter upon, but we will, in future lectures, see what was the nature of that work. We will perform before your eyes some of those operations by which that work has become of the utmost importance to mankind at large; and you can then see how, from a small point, there can be a light shed upon the largest problems of science.

In this year 1834, however, Liebig fell ill from overwork and anxiety. A portrait, which was taken at that time by the now deceased painter Engel, gives evidence of that, and I remember that the late Prof. Zamminer told me that he had seen Liebig about that time taking short walks in the evening air, looking pale and haggard, like a man in consumption, with little spots of hectic on his cheeks, and that his friends were afraid he would soon die. At that time he retired from Giessen for a while, and went to Baden-Baden, in the hope of recruiting his health. The patience which he had exercised for many years, under the most narrow arrangements, then gave way, and he asked for the building of a new lecture-room, the arrangement of a proper laboratory, and for an increase of salary. All was refused by the narrow-minded Government of Hesse-Darmstadt, through that close-minded man, the then chancellor, Von Linde. Then Liebig wrote to Von Linde a letter, in which, after the introduction, he continues thus:

> "I should have gained some convenience by these arrangements, but they were not intended for me personally; they would have been of lasting value for the university, and would have secured to the chemical chair an advantage over

all others in Germany. For the institutions of a university the largest sums may be expended, for this increases the respect and affection for them; but the suitable employment of these sums must be strictly controlled. The sums are there, but they are used in an intolerably ridiculous manner. I must be certain of what I may have to expect at Giessen. If driven to extremities I shall not return there this winter, whether I obtain leave or not. I shall know how to justify this step, for no one has been maltreated in the university in a more conspicuous manner. One cannot live at Giessen upon a salary of 800 florins. Four years ago I, in conjunction with four colleagues, asked for an increase of salary; it has been refused. You (the Chancellor von Linde) have assured me with smiles that the state treasury had no funds; from this I saw that you have never known grief and torturing care for the daily bread. From the moment of that refusal I have endeavored to acquire an independent position by ceaseless work; my exertions have not been without success, but they have surpassed my strength, and I have become an invalid; and if now, when I do not require the state any longer, I consider that with a few miserable hundred florins more my health need not have suffered in former years, because my life would have been more free from care, the hardest thought for me is that my situation was known to you. The means which the laboratory possesses have been too small from the beginning. I had four walls given to me instead of a furnished laboratory. Notwithstanding my requests, no sum for furnishing the same, or for buying apparatus, has been provided. I required instruments and specimens, and have been obliged to spend on these items annually from 300 to 400 florins from my own means; besides the *famulus* paid by the state I required an assistant, who costs me 320 florins—deduct both expenses from my salary, and there remains not enough to clothe my children. From this original treatment of the laboratory the consequence has arisen that it possesses no property, for I can show that the arrangements, fittings, instruments, specimens, which have made the Giessen laboratory—I can say it without blushing—the first in Germany, are my property. I will say nothing more about myself—my account with Giessen is closed. My path is not the one of reptiles, the easiest though the dirtiest. What I have said will suffice to justify with the ministry and the prince my resolution not to lecture at Giessen during this winter (1834–'35). If I am in health I may not lack the power to establish a kind of university for my branches of science at my own risk. If I am not permitted, and if I receive my *congé*, this will free me from the charge of ingratitude toward the country from the means of which my scientific training has been possible. I have learned to bear much injustice, many a false judgment, but this reproach of ingratitude would be too heavy for me to bear."

This letter pictures to you the conditions which prevailed at Darmstadt, but it is still more important, because it shows that such strong language was required to bring down the ministry, and that which no kind of friendly representation had been able to effect, this threat did. In 1835 he had to take compulsory repose. I find in the list of his publications only three small papers dating from this period, of which one only was a research; but in almost every other year there were from ten to twenty researches and publications.

In 1836 another active period begins. In that year there were nine researches by himself alone, thirteen by himself and Pelouze. In 1837 there were nine researches by himself and five with Wöhler, including the celebrated one on lithic acid, and two with the celebrated French chemist Dumas. In that year the British Association for the Advancement of Science, at their Liverpool meeting, made a request to him to write a report on the then state of knowledge of organic chemistry. It was this report which originated the work which he published in 1840, namely, the work entitled "Organic Chemistry in its Application to Agriculture and Physiology." In 1838 he published a memoir on the state of chemistry in Austria, in which he exhibited its shortcomings in trenchant language, and the effect upon the Austrian Government was such as no one would have expected. In reply to his essay he received the offer of a chair at Vienna. "Come to us," they said, "reform our chemistry, and we will give you a chair." But the conditions were not sufficient, and the Austrian Government, having received Liebig's refusal to go to Vienna, at their own expense sent a number of young chemists to Giessen, there to study chemistry under Liebig, and to prepare themselves for the important function of becoming teachers of the new chemistry in Austria. In the year 1840 he published the work which I have already mentioned, and he also published a memoir on the state of chemistry in Prussia. You know what was the state of Prussia in 1840; the promises made by the king in the year 1813, regarding a liberal constitution, had all been falsified, a narrow-minded bureaucracy governed everything, a minister of education who did not comprehend his time could not understand that physical science required any promotion, or any state help. He soon went into that movement which has been described as *Muckerthum*, a kind of pietism which shows itself by casting up the eyes in a praying attitude, having God more on the tongue than in the heart; by a mock-modest morality which would, for example, have caused the council of this institution to have those beautiful nymphs on our walls painted over with drapery. Under these circumstances no science could progress, and there was not in the whole of Prussia a single establishment, laboratory, or teaching-room where a man could learn practical or even theoretical chemistry. It was the great boast of even talented teachers of chemistry, that all the apparatus they required for teaching was a dozen test-tubes. This attack on the state of chemistry in Prussia had no effect whatever of a good kind, but, on the contrary, the bureaucracy used its power and influence to prevent the Prussian youth from visiting the University of Giessen, and I have the authority of Kolbe that for a time the visiting this university was actually forbidden to young Prussians.

About this period Liebig purchased from the municipality of Giessen a sand-pit, at a place called Trieb, on a little height east of the town, and there he made experiments on vegetable physiology. This place bears the name of "Liebig's Height" to the present day, and I dare say it will bear it for many years to come. He also published his work on "Chemistry in its Application to Physiology and Pathology," which he dedicated to Berzelius. In 1844 appeared his first "Familiar Letters on Chemistry," in the *Augsburg Gazette.* These letters were afterward published with many new ones from time to time in several editions, and by this means he contributed greatly to make chemistry popular, while still keeping it in the most scientific form needful. In 1850 he published a pamphlet on spontaneous combustion, on the occasion of the death of the Countess Görlitz, who had by experts and doctors at Darmstadt and Giessen been declared to have perished from spontaneous combustion, but it was afterward found out that she had not perished in that way, but that she had been murdered by her butler, and afterward burnt. About this time also Liebig effected a reform in the medical studies and examinations in the University of Giessen, and this reform was so important, and effected by so great a participation of public opinion, that we see there how great was his power, although in the university itself he was kept out of office as far as possible. These reforms amounted to nothing less than this—complete liberty of study. You know that in this country medical students have no liberty of study; they are obliged to attend lectures, to have heard at least two-thirds of the lectures given, and if it is not certified by the beadle, who comes in to every lecture and takes the names of all present, that they have been present at two-thirds of the lectures, they are not allowed to enter for the examination. This state of things also existed in the German universities previous to this reformation. At that time, however, this was completely done away with, and every student was allowed to obtain his knowledge where and how he pleased. He was not obliged to enter any university whatever, but he was obliged to pass an examination, and to pass that examination publicly, an examination which should so thoroughly test his knowledge that, after he had passed it there could be no doubt whatever about his fitness to follow his profession. Now let me recommend to your attention this most remarkable system of public examination. The extraordinary effect it had on the University of Giessen was this, that, whereas formerly many students coming unprepared were rejected, since the introduction of public examinations few rejections have taken place, because the students take great care to get up their subjects and to come so fully prepared that, in the presence of their countrymen, in the presence of any person who likes to enter the hall when the examination takes place, they can show that they are fit to follow their profession.

I have already, I see, passed the time allotted to me, and I shall not detain you many more minutes. In the autumn of the year 1852 Liebig left Giessen, having received a call to the University of München, where the then King Maximilian was desirous of following his father, Ludwig, on another path of glory. You know that Ludwig had made it his life-business to restore art in Germany and raise it to a high footing in Bavaria, and Maximilian now wished to do the same thing for science in general, and he therefore endeavored to collect from all parts of Germany the best men whom he could attract. One of these was Liebig, the king having made him president of the Academy, with the condition that he should undertake no laboratory teaching; that he should deliver lectures only, and at the same time be the Curator of the Botanical Gardens. In that position he remained up to his death, devoting himself mainly to the public part of his duties, which he performed with grace, honor, and glory, and in the laboratory which had been constructed for his own immediate wants he only performed such analyses, partly himself, and partly by a number of assistants, as were necessary to give him the data for the publication of his several works.

At last, in the year 1873, on April 18th, he died, nearly seventy years of age, and in full possession of his faculties, not having, as other philosophers have had the pain of doing, experienced any diminution of his mental powers.

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# CAROLINE LUCRETIA HERSCHEL.

By ELIZA A. YOUMANS.

## II.

WHATEVER may be thought of the intellectual differences between men and women, the broad mental contrast between Caroline Herschal and her brother Sir William Herschel is undeniable. Intellectual activity and a love of knowledge for its own sake influenced his boyhood, characterized his manhood, and dominated his whole life. He became an eminent astronomer because his passion for physical inquiry, directed toward the constitution of the universe, mastered every other sentiment of his nature. But the mind of Caroline Herschel was of another mould. She learned various things, from a desire to please her friends and to earn her living; but there is no evidence that she ever studied anything from a love of knowledge. Her whole life was inspired by purely personal feelings. In a former article we saw how submissively she delved for the family throughout her youth, and left them full of concern about their daily comforts. It was an all-absorbing love for her brother which led her to study astronomy, and at his death her devotion to science ended. Some people, perhaps, will admire her less on this account; yet, while it diminishes her claims as a philosopher, it certainly increases her claims as a woman. The tendency of women to act from intense personal motives is a fact of vital moment to the community, because the very existence of the family depends upon it; and it is difficult to imagine any future phase of society, of which the family is a factor, where engrossing personal feeling will not continue to be a supreme womanly trait.

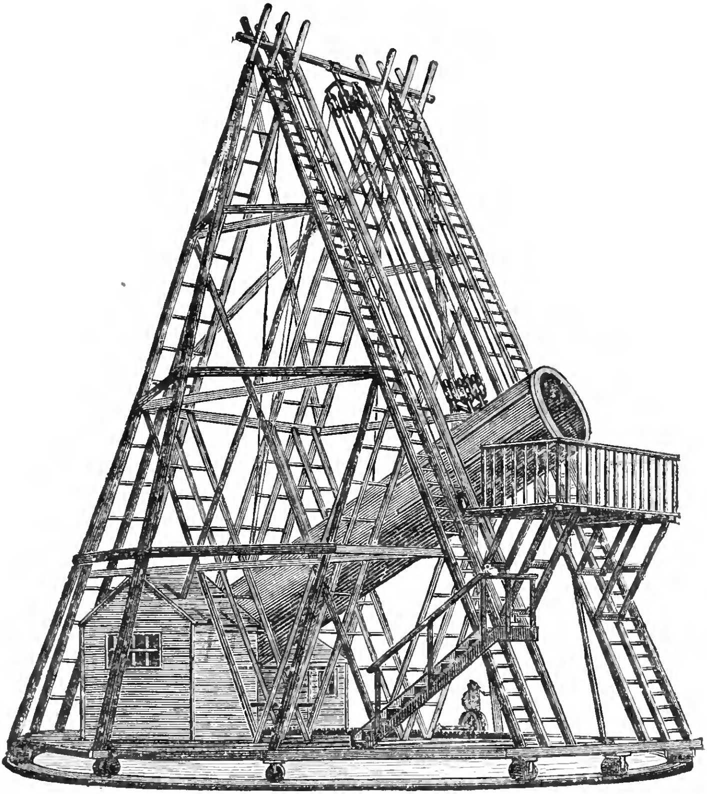
Resuming our history, we find that on the 1st of August, 1782, the Herschels with their instruments and furniture arrived at Datchet, and took possession of a large and neglected old house, with garden and grounds overgrown with weeds. Having no female servant, Miss Herschel was shown the shops by the gardener's wife, and her practical sense was at once shocked at the prices of everything, from coal to butcher's meat. But her brother was not disturbed by such considerations. He had stables where he could grind mirrors, a roomy laundry for a library, a large grass-plot for his instruments, and "he gayly assured her that they could live on eggs and bacon, which would cost nothing to speak of, now they were really in the country." After a couple of months the younger brother went back to Bath to resume his occupations in music; and it was this separation which awakened Caroline to a consciousness of what she was doing in giving up the prospect of becoming independent in the musical profession. But she reconciled herself to the situation by the thought that her brother William could not do without her, and that she had not spirit enough to throw herself upon the public without his protection. Soon after Alexander's departure, William had to go away for a week or ten days, and she was left alone. She thus describes her feelings in entering upon her new work:

> "In my brother's absence from home, I was, of course, left solely to amuse myself with my own thoughts, which were anything but cheerful. I found I was to be trained for an assistant astronomer, and, by way of encouragement, a telescope adapted for 'sweeping,' consisting of a tube with two glasses, such as are commonly used in a 'finder,' was given me. I was 'to sweep for comets,' and I see by my journal that I began August 22, 1782, to write down and describe all remarkable appearances I saw in my 'sweeps,' which were horizontal. But it was not till the last two months of the same year that I felt the least encouragement to spend the starlight nights on a grass-plot covered with dew or hoar-frost, without a human being near enough to be within call; for I knew too little of the real heavens to be able to point out every object so as to find it again without losing too much time by consulting the atlas. But all these troubles were removed when I knew my brother to be at no great distance, making observations with his various instruments on double stars, planets, etc., and I could have his assistance immediately when I found a nebula, or cluster of stars, of which I intended to give a catalogue; but, at the end of 1783, I had only marked fourteen, when my sweeping was interrupted by being employed to write down my brother's observations with the large twenty-foot. I had, however, the comfort to see that my brother was satisfied with my endeavors to assist him when he wanted another person, either to run to the clocks, write down a memorandum, fetch and carry instruments, or measure the ground with poles, etc., of which something of the kind every moment would occur."

The summer months of 1783 were spent in getting the large twenty-foot ready for the next winter. After some account of her brother's many and incessant occupations, she says he also threw away some trouble in the effort to teach her to remeasure double stars with the micrometers used in former measurements, and a small twenty-foot was given her for the purpose. She had also to use a borrowed transit-instrument to find their places, but after many failures it was seen that the instrument was as much in fault as herself. She thus continues her account of her experiences:

> "July 8th (1783) I began to use the Newtonian small sweeper, but it could hardly be expected that I should meet with any comets in the part of the heavens where I swept, for I generally chose my situation by the side of my brother's instrument, that I might be ready to run to the clock or write down memorandums. In the beginning of December I became entirely attached to the writing-desk, and had seldom an opportunity after that time of using my newly-acquired instrument. My brother began his series of sweeps when the instrument was yet in a very unfinished state, and my feelings were not very comfortable when every moment I was alarmed by a crack or fall, knowing him to be elevated fifteen feet or more on a temporary cross-beam instead of a safe gallery. The ladders had not even their braces at the bottom; and one night, in a very high wind, he had hardly touched the ground before the whole apparatus came down. Some laboring-men were called up to help in extricating the mirror, which was fortunately uninjured; but much work was cut out for carpenters next day. That my fears of danger and accidents were not wholly imaginary, I had an unlucky proof on the night of the 31st of December. The evening had been cloudy, but about ten o'clock a few stars became visible, and in the greatest hurry all was got ready for observing. My brother, at the front of the telescope, directed me to make some alteration in the lateral motion, which was done by machinery, on which the point of support of the tube and mirror rested. At each end of the machine or trough was an iron hook, such as butchers use for hanging their joints upon, and, having to run in the dark on ground covered a foot deep with melting snow, I fell on one of these hooks, which entered my right leg above the knee. My brother's call, 'Make haste!' I could only answer by a pitiful cry, 'I am hooked!' He and the workmen were instantly with me, but they could not lift me without leaving nearly two ounces of my flesh behind. The workman's wife was called, but was afraid to do anything, and I was obliged to be my own surgeon by applying aquabusade and tying a kerchief about it for some days, till Dr. Lind, hearing of my accident, brought me ointment and lint, and told me how to use them. At the end of six weeks I began to have some fears about my poor limb, and asked again for Dr. Lind's opinion; he said if a soldier had met with such a hurt he would have been entitled to six weeks' nursing in a hospital. I had, however, the comfort to know that my brother was no loser through this accident, for the remainder of the night was cloudy, and several nights afterward afforded only a few short intervals favorable for sweeping, and, until the 16th of January, there was no necessity for my exposing myself for a whole night to the severity of the season. I could give a pretty long list of accidents which were near proving fatal to my brother as well as myself."

Her account of the years 1784 and 1785 is varied by reminiscences of the trouble her brother had in trying to live and pursue his astronomical observations on £200 a year. The book contains many incidental allusions to royal patronage that are not flattering; but, notwithstanding the silence of her diary upon so many matters of real consequence, she always chronicles the attentions bestowed upon her brother and herself by kings and nobles. Most of her brother's time was spent in making and selling telescopes for other observers, instead of finishing a thirty or forty foot instrument for his own use, upon which his heart was set. The king ordered many seven-foot and four ten-foot telescopes, one of which was to be sent as a present to the observatory at Göttingen. Meantime, through the influence of Sir Joseph Banks, £2,000 had been granted to Herschel, to enable him to make an instrument for himself. After living in Datchet four years, they moved to Slough, in April, 1786, and it was here that Herschel put up his famous telescope, and fixed his residence for the rest of his life.



Sir William Herschel's Forty-foot Telescope at Slough.

In July of this year he went to Germany to deliver the ten-foot telescope from the king, leaving Caroline in charge of matters at home. The stand for the forty-foot telescope was finished, and he left a smith at work on the tube. The mirror was also pretty far advanced. During this absence of her brother Miss Herschel discovered her first comet. Her diary and letters belonging to this period are very interesting. Her brother left on the 3d, and on that day she cleaned and put the polishing-room in order, made the gardener clear the work-yard, and mend the fences. "5*th.*—Spent the morning in needle-work . . . ." "6*th.*—Put the philosophical letters in order, and the collection of each year in a separate corner . . . ." "12*th.*—Put paper in press for a register . . . ." "18*th.*—Spent the day in ruling paper for the register, except that at breakfast I cut out ruffles for shirts . . . ." "29*th.*—I paid the smith . . . ."

It was on the 1st of August that she first saw the comet. We give her diary at this time in full:

> "*August 1st.*—I have counted 100 nebulæ to-day; and this evening I saw an object which, I believe, to-morrow night will prove to be a comet.
>
> "2*d.*—To-day I calculated 150 nebulæ. I fear it will not be clear to-night. It has been raining throughout the whole day, but seems now to clear up a little. *One o'clock.*—The object of last night *is a comet.*
>
> "3*d.*—I did not go to rest till I had wrote to Dr. Blagden and Mr. Aubert, to announce the comet."

In the letter to Dr. Blagden she says:

> "The employment of writing down the observations when my brother uses the twenty-foot reflector does not often allow me time to look at the heavens; but, as he is now on a visit to Germany, I have taken the opportunity to sweep in the neighborhood of the sun in search of comets; and last night, the 1st of August, about ten o'clock, I found an object very much resembling in color and brightness the 27 nebulæ of the *Connoissance des Temps*, with the difference, however, of being round. I suspected it to be a comet; but, a haziness coming on, it was not possible to satisfy myself as to its motion till this evening."

After describing the object and its position, she concludes:

> "You will do me the favor of communicating these observations to my brother's astronomical friends."

Dr. Blagden replied on August 5th that no one but herself had yet seen the comet, but that he had spread the news of her discovery in England, France, and Germany. August 7th Mr. Aubert wrote to her that he did not find the comet till the 5th on account of cloudy weather. He says:

> "I wish you joy most sincerely on the discovery. I am more pleased than you can well conceive that *you* have made it, and I think I see your *wonderfully clever* and *wonderfully amiable* brother, upon the news of it, shed a tear of joy. You have immortalized your name, and you deserve such a reward for your assiduity in the business of astronomy, and for your love for so celebrated and deserving a brother."

We give place to the friendly expressions of these gentlemen, and others that will follow, to show that Miss Herschel was not hindered in her scientific career by the jealousy or antagonism of male rivals, of which ambitious women complain so much in these degenerate days. She continues the diary of her labors:

> "*4th.*—I wrote to Hanover; booked my observations; made accounts. The night is cloudy.
>
> "*5th.*—Calculated nebulæ all day. The night was tolerably fine, and I saw the comet.
>
> "*6th.*—I booked my observations of last night. Received a letter from Dr. Blagden in the morning, and in the evening Sir J. Banks, Lord Palmerston, and Dr. Blagden, came and saw the comet. The evening was very fine.
>
> "*7th and 8th.*—Booked my observations. On the 8th the evening was cloudy.
>
> "*9th.*—I calculated 100 nebulæ.
>
> "*10th.*—Calculated 100 nebulæ. The smith borrowed a guinea.
>
> "*11th.*—I completed, to-day, the catalogue of the first thousand.
>
> "*13th.*—Prof. Kratzensteine, from Copenhagen, was here to-day. In the evening I saw the comet, and swept.
>
> "*14th.*—I calculated 140 nebulæ to-day, which brought me up to the last-discovered nebulæ, and therefore the work is finished."

Miss Herschel says it is impossible for her to give an account of all that passed around her in the following two years, for they were spent in a perfect chaos of business.

But in 1788, after he was fifty years old, her brother married a wealthy widow, of about the same age as Miss Herschel. It is said by the editor that the wife was very amiable and gentle, and that the jointure she brought enabled her husband to pursue his scientific career without anxiety about expenses. But this was evidently not so. We must infer from the statements of Miss Herschel that this wealth, like royal patronage, was not applied to relieve Sir William from drudgery; for, to the end of her brother's life, she complains that, instead of pursuing original investigations, he had to spend an enormous amount of time and labor making and selling telescopes; and that the fatigue and exhaustion from polishing mirrors told seriously upon his health. In 1805, more than a dozen years after his marriage, we hear of his finishing an instrument for the King of Spain, and at about the same time another for the Prince of Canino. She further says that he was miserably stinted for room for his instruments, and continually bemoans the embarrassments and hinderances which defeated his plans of study, and asserts that, during the last years of his life, his spirits were depressed and his temper soured by these circumstances.

In her diary, all that Miss Herschel says of her brother's marriage is this:

> "It may easily be supposed that I must have been fully employed (besides minding the heavens) to prepare everything as well as I could against the time I was to give up the place of housekeeper on the 8th of May."

When, in after-years, she was preparing the materials for her biography, which were to be sent to Sir John Herschel, the son of this new sister-in-law, she destroyed all her diary and records for the ten years immediately succeeding her brother's marriage. Her biographer and relative alludes to her experiences at this time in the following language:

> "With saddened heart but unflagging determination she continued to work for her brother, but saw his domestic happiness pass into other keeping. It is not to be supposed, however, that a nature so strong and a heart so affectionate should accept the new state of things without much and bitter suffering. To resign the supreme place by her brother's side, which she had filled for sixteen years with such hearty devotion, could not be otherwise than painful in any case; but how much more so in this, where equal devotion to the same pursuit must have made identity of interest and purpose as complete as it is rare! One who could both feel and express herself so strongly was not likely to fall into her new place without some outward expression of what it cost her—tradition confirms the assumption—and it is easy to understand how this long, significant silence is due to the light of later wisdom and calmer judgment which counseled the destruction of all record of what was likely to be painful to survivors."

In reference to Herschel's marriage, a writer in the London *Examiner* says, "It is impossible to regret or censure the step which gave existence to his yet more remarkable son;" but this is a singular and tardy justification. In marrying, he did what it was highly probable he would do; and, remembering this, he should not have allowed his sister to live so entirely for him. It is not to be supposed, however, that he foresaw the unpleasant consequences that fell upon her. When the temptation to marry came, he no doubt stupidly fancied that in enriching his own life by this new relation he should add to her happiness by bringing her a sister; but, if he had studied the ways of men and women as he studied the heavens, he might have saved himself from such a delusion.

The work she did during the next ten years affords abundant evidence of the heroism with which Miss Herschel met her fate. Besides discovering seven more comets, she prepared "A Catalogue of 860 Stars observed by Flamstead, but not included in the British Catalogue," and "A General Index of Reference to Every Observation of Every Star in the above-mentioned British Catalogue," both of which works were published by the Royal Society in 1798. She also spent much time upon another work which was not finished for many years. It was "The Reduction and Arrangement in the Form of a Catalogue, in Zones, of all the Star-Clusters and Nebulæ observed by Sir W. Herschel in his Sweeps." For this she received the gold medal of the Royal Astronomical Society in 1828, and it was pronounced by Sir David Brewster "a work of immense labor."

Some account of her discoveries was found in a packet wrapped in coarse paper, and labeled "This is what I call the bills and receipts of my comets." The separate parcels of this bundle were marked

"First Comet," "Second Comet," etc. She announced the discovery of her second comet to Dr. Maskelyne, the royal astronomer, in the following letter, with a postscript by her brother:

> "DEAR SIR: Last night, December 21st, at $7^h$ 45′, I discovered a comet, a little more than one degree south, preceding $\beta$ Lyræ. This morning, between five and six, I saw it again, when it appeared to have moved about a quarter of a degree toward $\delta$ of the same constellation. I beg the favor of you to take it under your protection.
>
> "Mrs. Herschel and my brothers join with me in compliments to Mrs. Maskelyne and yourself, and I have the honor to remain,
>
> "Dear sir, your most obliged, humble servant,
>
> "CAROLINE HERSCHEL.
>
> "SLOUGH, *December* 22, 1788."
>
> "P. S.—The comet precedes $\beta$ Lyræ $7' 5''$ in time, and is in the parallel of the small star ($\beta$ being double). *See* fifth class, third star, of my catalogue.
>
> "WILLIAM HERSCHEL."

Her brother announced her discovery to Sir J. Banks and Sir H. Englefield, and from these gentlemen she received the most cordial congratulations. Two years later, on January 7, 1790, the third comet was discovered, and on the 17th of April, the same year, when her brother was absent, she announced her fourth comet to Sir Joseph Banks in the following words:

> "*April* 19*th*.
>
> "SIR: I am very unwilling to trouble you with incomplete observations, and for that reason did not acquaint you yesterday with the discovery of a comet. I wrote an account of it to Dr. Maskelyne and Mr. Aubert, in hopes that one of them would furnish me with the means of pointing it out in a proper manner. But as several days may pass before my letters are answered, or my brother returns, I would not be thought neglectful, and if you think the following description sufficient, and that more of my brother's astronomical friends should be made acquainted with it, I should be very happy if you would be so kind as to do it for the sake of astronomy."

Then follows an account of the comet. The letter, written on the day previous, to Mr. Aubert, we give entire:

> "SLOUGH, *April* 18, 1790.
>
> "DEAR SIR: I am almost ashamed to write you, because I never think of doing so but when I am in distress. I found, last night, at $16^h$ 24′, sidereal time, a comet, and do not know what to do with it, for my new sweeper is not half finished; and, besides, I broke the handle of the perpendicular motion in my brother's absence (who is on a little tour in Yorkshire). He furnished me to that instrument a rhomboides, but the wires are too thin, and I have no means for illuminating them. All my hopes were that I should find nothing to make me feel the want of these things in his absence; but, as it happens, here is an object in a place where there is no nebula, or anything which could look like a comet, and I would be much obliged to you, sir, if you would look at the place where the annexed eye-draft will direct you to. My brother has swept that part of the heavens, and has many nebulæ there, but none which I must expect to see with my instrument. I will not write to Sir J. Banks or Dr. Maskelyne,

or anybody, till you, sir, have seen it; but if you could, without much trouble, give my best respects, and that part of this letter which points out the place of the comet, to Mr. Wollaston, you would make me very happy.

"I am, dear sir, etc., etc., C. H."

From all these gentlemen her labors and discoveries received the most cordial recognition. In his reply, Sir J. Banks said: "I shall take care to make our astronomical friends acquainted with the obligations they are under to your diligence." Mr. Aubert closes his letter with the assurance of the pleasure he felt at her success, and with the offer of any instrument she might wish to use; while Dr. Maskelyne addressed her as his "worthy sister in astronomy."

The fifth comet was discovered December 15, 1791, and all that she says about it is, "My brother wrote an account of it to Sir J. Banks, Dr. Maskelyne, and several other gentlemen." The sixth, found October 8th, is briefly recognized; and the seventh, discovered November 7, 1795, is known as Encke's comet, because he determined its periodicity. It was discovered by four different observers before its identity was recognized. Miss Herschel was its second discoverer in order of time. Her eighth and last comet was discovered August 6, 1797.

We learn from her diary that in October of this year her home with her brother at Slough was broken up, and she went to live in solitude in lodgings, and this mode of life she continued for twenty-five years, till her brother's death, when she left England to join her relations in Hanover. Why she left her brother's house she does not explain, nor is it necessary. In referring to her departure she only says: "My telescopes on the roof, to which I was to have occasional access, as also the room with the sweeping and observing apparatus, remained in their former order, where I most days spent some hours in preparing work to go on with at my lodgings." In a letter to Dr. Maskelyne, written in September, 1798, she says that, during the past year, she has not thought herself "well or in spirits enough to venture from home." She spent her first lonely winter in getting ready for the press some of her own astronomical work.

The account of her life from 1798 until her brother's death, in 1822, occupies about fifty pages of the volume, and consists mostly of extracts from her diary. It is not a record of discoveries or personal triumphs, but of unceasing labor for her brother, knowing no respite in sickness or in health, by night or by day, in winter or in summer, amid hardships and discouragements that never daunted her affectionate nature. During her first year in lodgings, she complains of being harassed by the loss of time in going backward and forward, and by not having immediate access to books and papers; and these troubles, with varying features, pursued her to the end of her brother's life. The first three or four years she changed her lodgings often, but in 1801 she settled in Upton, where she remained till 1810, at which time she took possession of a cottage in Slough, belonging to her brother, and, although mention is made in her diary of moving again in 1814, yet she continued to live in Slough.

Notwithstanding all her prudence about paining relations, the multiplied repetition in her diary of such entries as the following is painfully suggestive:

"*March 5th.*—Went to make some stay with my brothers at Slough, Mrs. Herschel being in town.

"*27th.*—All returned, and I went with my work to Upton again.

"*September 24th.*—Went to work with my brother at Slough.

"*October 1st.*—Mrs. Herschel and niece returned. I went back to Upton.

"*August 1st.*—I left Upton for Slough. My brother went with Mrs. Herschel and Miss Baldwin on an excursion. I distracted my thoughts by undertaking an amazing deal of work.

"*September 8th.*—My brother and family returned, and I went with my works to Upton.

"*May 2d.*—I left Upton for Slough to work with my brother; Mrs. Herschel being in town till June 18th.

"*November 3d.*—I came home to Upton (Mrs. Herschel returned from Brighton), but went most days to assist my brother in the polishing-room or library, and, from the 10th of December to the 22d, was entirely at Slough, Mrs. Herschel being away.

"*January.*—I had a cough all the month; the communication between Slough and Upton very troublesome to me.

"*March 9th.*—Went to Slough to work with my brother; his family from home.

"*May 11th.*—Went to be with my brother; Mrs. Herschel went to town for a month.

"*June 12th.*—Mrs. Herschel returned from town, and I went home."

It is pleasant to find, however, that the asperities of this period of her life were so much softened by time and distance that in 1829, when living in Hanover, she was able to write to her sister-in-law, confidentially as to "a dear sister, for as such I now know you."

The diary closes in 1822, with an account of her brother's death, and her departure from England. We quote the following characteristic passage relating to this period. She had come as usual to spend the morning with her brother:

"*August 15th.*—I hastened to the spot where I was wont to find him, with the newspaper which I was to read to him. But instead I found Mrs. Morson, Miss Baldwin, and Mr. Bulman, from Leeds, the grandson of my brother's earliest acquaintance in this country. I was informed my brother had been obliged to return to his room, whither I flew immediately. Lady Herschel and the housekeeper were with him, administering everything which could be thought of for supporting him. I found him much irritated at not being able to grant Mr. Bulman's request for some token of remembrance for his father. As soon as he saw me, I was sent to the library to fetch one of his last papers, and a plate of the forty-foot telescope. But, for the universe, I could not have looked twice at what I had snatched from the shelf, and when he faintly asked if the breaking up of the milky-way was in it, I said 'Yes,' and he looked content. I cannot help remembering this circumstance: it was the last time I was sent to the library on such an occasion."

Her brother William died on the 25th of August, and in the following October she settled in Hanover with her brother Dietrich.

When her brother died she was herself in feeble health, and expected soon to follow him to the grave, and it suited her feelings to go back to Hanover to die. Besides, she says:

> "My whole life almost has passed away in the delusion that, next to my eldest brother, none but Dietrich was capable of giving me advice where to leave my few relics, consisting of a few books and my sweeper. And for the last twenty years I kept to the resolution of never opening my lips to my dear brother William about worldly or serious concerns, let me be ever so much at a loss for knowing right from wrong. And so it happened that, at a time when I was stupefied by grief at seeing the death of my dear brother, I gave myself with all I was worth (£500 of bank-stock) to my brother Dietrich and his family, and, from that time till the death of Dietrich, I found great difficulty to remain mistress of my own actions and opinions. In respect to the latter we never could agree."

Her brother William, however, left her a legacy of £100 a year, and during the rest of her life her chief study was how to spend this sum without making herself ridiculous.

As was to be expected, after fifty years' absence she found Hanover changed in everything, and little to her taste, and she was also grievously disappointed in the generation of relatives with whom she lived, and of whom she says:

> "They have never been of the least use to me, and for all the good I have lavished on them they never came to look after me, but when they had some design upon me."

In speaking of her return to Hanover, her biographer writes thus:

> "Who can think of her at the age of seventy-two, heart-broken and desolate, going back to the home of her youth to find consolation without a pang of pity? She little guessed how much her habits had changed in the different world where she had lived for fifty years. She had the bitterness to find herself alone with her great sorrow."

We have no space to give to this part of her life, although it occupies more than half of the volume, to which we must refer our readers. It is made up chiefly of her correspondence, and her letters, from their unconscious self-portraiture, are quite as interesting as her "Diary" or her "Recollections." It is full of interest also on account of the details it gives concerning the life of Sir William Herschel, of whom no reliable biography has yet appeared.

She died peacefully in 1848, and her funeral was held in the same garrison-church where she was christened and confirmed. According to a request made to her favorite niece, a lock of her brother's hair, and an almost obliterated almanac, that had been used by her father, were placed with her in her coffin. The same niece, in a letter written at this time to her cousin, Sir John Herschel, says:

> "I felt almost a sense of joyful relief at the death of my aunt, in the thought that now the unquiet heart was at rest. All that she had of love to give was concentrated on her beloved brother. . . . She looked upon progress in science as so much detraction from her brother's fame, and even your investigations would have become a source of estrangement had she been with you."

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# AWARDS AT THE INTERNATIONAL EXHIBITION.

## REPORT OF HON. N. M. BECKWITH, COMMISSIONER FROM NEW YORK, ON THE SELECTION AND APPOINTMENT OF JUDGES.

AT a regular meeting of the Executive Committee of the United States Centennial Commission, held at Philadelphia, October 13, 1875, Mr. Beckwith, Commissioner from New York (United States Commissioner-General at the International Exhibition at Paris, 1867), presented the following report upon the selection and appointment of judges. It was carefully considered and unanimously approved:

HON. D. J. MORRELL, *Chairman of the Executive Committee.*

SIR: In compliance with the request of the Executive Committee, I beg leave to present for consideration the following suggestions relating to the selection and appointment of judges, in conformity with the method of awards decreed by the Centennial Commission.

This method, in many respects, differs radically from the systems hitherto tried in International Exhibitions, and, although the subject is familiar to you, I shall be pardoned, I hope, for briefly indicating the broad differences.

Awards have heretofore been generally made by an International Jury of about six hundred members.

The apportionment of jurors to countries has been tried on various bases, but was usually made on the basis of the relative space occupied by the products of each country respectively, in the Exhibition.

The Great Jury was divided into numerous small juries, who examined the products and prepared lists of the names of persons whom they proposed for awards, and the proposals thus made were confirmed or rejected by higher juries.

The awards consisted chiefly of medals of differents values, gold, silver, etc.

This system brought together a numerous and incongruous assembly, including unavoidably many individuals unqualified for the work.

The basis of representation was apparently fair, but its results were delusive.

A few countries nearest the Exhibition, whose products could be collected and exposed at the smallest proportional expense, occupied large spaces; the numerous remote countries filled smaller spaces.

The number of jurors allotted to the smaller spaces, when distributed, left them without jurors on most classes, and in the remainder with only a minority which, in voting on awards, had no weight, and the awards were thus in effect decreed by the few contiguous countries whose products filled the largest spaces. Written reports on the products were not usually made by juries, and, if made, were not generally published; consequently no person outside of the jury was informed on what ground awards were made.

The medals, when distributed, were as silent as the verdicts; moral responsibility for the decisions attached to no one, and the awards thus made conveyed as little useful information, and carried as little weight, as anonymous work usually carries.

Medals, at best, are enigmas. They express nothing exactly and definitely relative to the products exhibited; their allegorical designs doubtless have a meaning in the mind of the artist who makes them, but allegorical designs are primitive and feeble language, and the medal of to-day is no more than its predecessor, a schoolboy token — verdicts upon products determined by majority votes of juries in which the producing countries are often represented by useless minorities—awards based upon anonymous reports, or reports never published, and final decisions announced and recorded in the vague and mystic language of medals, have not proved satisfactory to producers nor to the public. As regards the diffusion of reliable and useful information, International Exhibitions have not come fully up to expectations and to the promise implied in the great labor and great expenses which they involved; and the wide-spread dissatisfaction which has uniformly followed the close of jury-work affords in itself strong evidence that the system is not well adapted to the purposes of International Exhibitions.

The method of awards adopted by the Centennial Commission differs from preceding systems. It dispenses with the International Jury, aud substitutes a body of two hundred judges, one-half foreign, chosen individually for their high qualifications.

It dispenses, also, with the system of awards by graduated medals, and requires of the judges written reports on the inherent and comparative merits of each product thought worthy of an award, setting forth the properties and qualities, presenting the considerations forming the ground of the award, and avouching each report by the signature of its author.

The professional judgment and moral responsibility of the judges being thus involved, assure the integrity of their reports. As awards to exhibitors, such reports will be more valuable than medals, in proportion to the greater amount of reliable information which they convey to the public. Their collected republication, as hand-books, will form valuable guides for all classes to the most advanced products of every country, and, *last and least*, the sales of them can hardly fail to return to the Commission a good portion of their cost.

The success of this method obviously depends on the judicious selection of the judges, and to this point I desire to call particular attention.

In this connection it may be remarked that the best judges of products are not usually found among their producers, but among their consumers.

To select a wine, for example, of particular character, one would not apply to wine-growers, but to dealers and consumers. On the merits of an engine, you would prefer the opinion of the engineer who uses it, to that of the engineer who invented or made it. The sugars and coffees of Brazil, Cuba, Java, etc., are best judged in the great markets of consumption. In brief, the food-products of the world find their most accurate appreciations, as regards their inherent qualities and comparative merits, in the great consuming markets, where similar products from all regions are gathered, and the practical judgment of the using and consuming public is pronounced, from which there is no appeal.

The principle in this applies not only to raw products, but in a general sense to manufactures and to industrial products of all kinds in general use.

In this view of the subject, the method of awards adopted by the Centennial Commission presents the great advantage that it is *judicial* rather than *representative*, and the Commission is perfectly free to select judges from the best sources, regardless of localities.

The men to seek for are those who, by their ability, education, character, and experience, are fittest for the work, and they will be less difficult to find than to obtain, being generally employed, and frequently connected with large industries, important works, and the higher institutions to which their superior qualifications have led them.

Freedom to choose our judges from the best sources cannot fail to produce good results if the selection be made upon proper investigation, with suitable care and without favor.

The announcement of this method of awards has been received in foreign countries, as far as heard from, with expressions of distinct approbation, and there can be no doubt that they will select and bring to us their hundred judges, who will be distinguished by their reliable and solid qualifications, and it is incumbent on us to select a body of men of character, able and expert in their respective callings, and equal in attainments and experience to our foreign coöperatives, with whom our own will be intimately associated.

I need hardly add that the useful results and success of our Exhibition and the public satisfaction which it should produce, as well as the reputation of this Commission, as practical and sensible men, depend largely on the selection of our judges, and finally upon their organization and work. . . .

Respectfully submitted, N. M. BECKWITH.

NEW YORK, *October* 9, 1875.

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# RECENT ADVANCES IN TELEGRAPHY.

By R. RIORDAN.

THE improvements in telegraphy, about which the public has lately been learning a good deal through the newspapers, really constitute a remarkable element of progress, and are deserving of separate consideration. With the fire-alarm, domestic, and district telegraphs in our cities, the reduced rates and increased efficiency of the great lines and the further improvements promised us, it does not seem too much to expect that the telegraph will soon rival the post-office and the press as a bearer and diffuser of intelligence.

The failure of the English postal telegraph to fulfill the sanguine prophecies of its advocates will hardly be held to militate against this view, when it shall be shown what the nature of these improvements is. Prof. Jevons, in a late number of the *Fortnightly Review*, has indicated the causes of this failure. It was taken for granted by the promoters of the scheme, he asserts, that, as in the case of the

Post-office, a vast increase of business might be done with but little more expense. Accordingly, to gain the increased business they reduced the rates one-half, and succeeded—but not in a pecuniary sense. Prof. Jevons ascribes this disappointing result to the great cost of erecting and maintaining the lines; to their small carrying capacity when compared with that of a railroad-train; and to the number of hands and *heads* which each telegraphic message has to pass through before reaching its destination, and which must all be paid. But the progress of the last five years, made principally in this country, has demonstrated that these difficulties are not insuperable.

In order of time, the first important step toward this end was the Duplex Telegraph of Mr. Joseph Stearns, of Boston, Massachusetts. Its object is to allow of two operators using the same wire to send messages in opposite directions simultaneously. To persons having only a general acquaintance with the ordinary working of the telegraph, this at first seemed impossible; and, when it was accomplished, it was held by many—some scientific men among the number—to furnish an indubitable proof of the theory that the electric waves, or currents, or whatever they might be held to be, necessarily passed each other in contrary directions over the wire. That they do not will be evident from the subjoined explanation.

It must be remembered that the galvanic battery gives birth to a force which returns in a circuit to where it was generated, and accelerates the liberation of more force, being like a steam-engine employed partly in fanning its own fire. This circuit can be performed much more easily through great lengths of some substances, such as the earth and metals, than through very small spaces of others, as the air and the dilute acid of the battery. Galvanic electricity is, therefore, strictly confined in a sort of mill-round; or it may best, for our present purposes, be represented by water flowing through such a system of water-courses as is shown in the annexed cut. We will suppose them to include a reservoir and a secondary circuit at each end. Let the reservoirs *A* and *B* have water pumped into them by force-pumps, and distributed by them to both the main and secondary circuits, in equal quantities and in the direction of the arrows, so as to maintain the water-wheels *X* and *W* in the same positions. The highest points in the system must be supposed to be at the front of the reservoirs, and the lowest at the back of them.

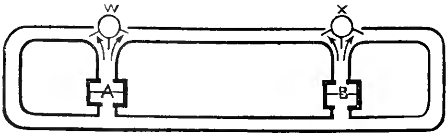

FIG. 1.

If an additional volume of water come from *A*, being equally divided on each side of *W*, it will not move that wheel, but it will move the wheel *X* by destroying the balance which previously existed there. But, if a similar extra volume be at the same time sent from *B*, the pressure in that part of the circuit between *W* and *X* will overcome the opposing forces at each of the points, and both wheels will be worked, each virtually by the distant reservoir and not by its own.

If we substitute galvanic batteries for the reservoirs, wires for the water-courses, and electricity for the water, this gives us the principle of the duplex telegraph, and it is obvious that no currents passing one another in contrary directions are necessary to it. It will be well to keep this in mind when we come to describe the quadruplex system.

Following the duplex, the American Automatic system may be said to have been perfected in 1873. The great rapidity with which messages are transmitted and recorded by it is its principal advantage, but it has others—as requiring a smaller force of operators and less specially skilled. The usual work of a Morse operator is acknowledged to be about 1,500 words an hour, and European operators do not average half as much; but, by the automatic method, to receive and print *double* that number of words per *minute* is an ordinary feat, and as many as 7,000 words—fourteen pages of this magazine—have been legibly recorded in that time. As every word contains, on an average, five letters, and as each letter is represented by a varying number of dots and dashes, each formed by a separate discharge, the circuit, it is calculated, must be "closed" and "broken," and the chemicals in the battery must cease and recommence their action 60,000 times per minute, in the ordinary working of the automatic system.

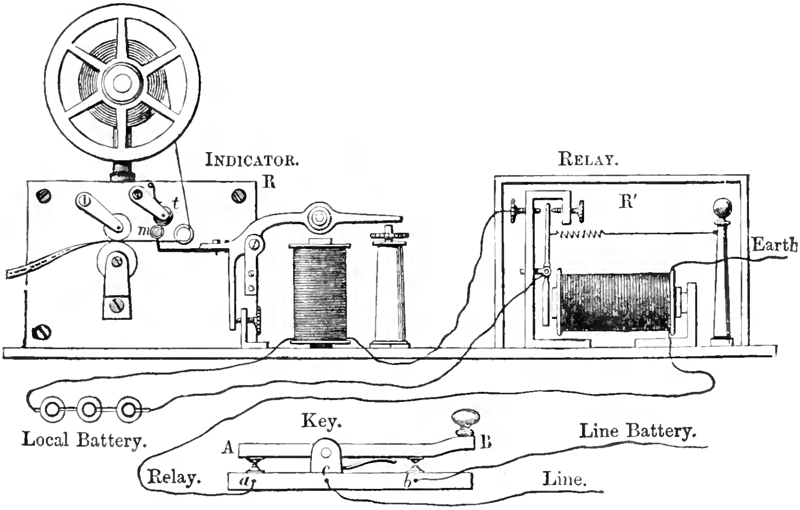

FIG. 2.—MORSE KEY AND REGISTER. (From Deschanel.)

In every form of electric telegraph the signals are given by an intermittent flow of electricity. In the Morse system a "key" is used which, in its normal position, "breaks" the circuit, but when depressed by the finger of the operator allows the electricity to pass through it on its mission. Arrived at the distant station, it is converted, by means of an electro-magnet, into mechanical motion, which is utilized either to produce indentations in a moving slip of paper by means of a style, or, more commonly, to give a series of taps, which the operator understands, by an instrument called a "sounder."

In the automatic system the means employed are altogether different. The message is, first of all, prepared by punching holes in a narrow ribbon of paper. These perforations are so grouped as to represent the dots and dashes of the telegraphic alphabet, and by the punching-machine, which is very complicated, all that are required to form a letter are punched at one stroke. In comparing the two systems this must not be lost sight of, as the time taken in punching must, of course, be added to the time of transmission. The machine, however, does its work more quickly than the Morse operator with his key, and, the time occupied in transmitting being so vastly less, the "automatic" may claim to have rendered old-fashioned telegraphy comparatively slow.

After the perforated slip of paper has been prepared, it is taken to the operator's table, where it is made to move forward rapidly between a metallic drum and a needle carrying two small steel wheels which rest upon it. Drum and wheels form part of the circuit, which is broken by the non-conducting paper interposed and closed when the holes permit of the wheels and the metallic cylinder beneath coming into contact. At the receiving-station a very similar arrangement does duty as a register. The paper slip is there saturated with a certain chemical solution which renders its whole substance a good conductor, and, instead of the wheels, there is an iron style or "pen." When electricity arrives over the line, it decomposes the moisture of the paper into oxygen and hydrogen, and oxidizes or rusts the pen.

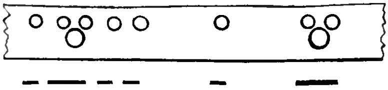

Fig. 3.

A little of this oxide is rubbed off by the quickly-moving paper, and enters into combination with the chemical still contained in it, producing a stain in the form of a dot or dash which corresponds with the holes punched in the paper at the sending-station. Where three holes come together, both wheels form a contact, and a dash is produced, because the second wheel touches the cylinder while the first passes over the paper between the upper holes.

The germ of the automatic system, as we have described it, was contained in the "Chemical Telegraph" invented by Alexander Bain, a Scotchman, in 1846. Bain was the first to use the perforated paper to transmit and the chemically-prepared paper to receive the message. But his invention, from a practical point of view, bears about the same relation to the American system which the steam-engine as known to the ancients does to that of James Watt. Bain's system, improved by the late Sir Charles Wheatstone and known as Wheatstone's automatic system, is employed to a limited extent in Great Britain; but, thus improved, its speed does not exceed 60 to 100 words a minute. It is therefore proper to regard the American Automatic Telegraph as a distinct American invention. In its present form, we owe it to Mr. Thomas A. Edison, of Newark, New Jersey.

The accompanying cut (Fig. 4) illustrates the results of attempting high speed on the Bain telegraph. Instead of recording themselves by decided dots and dashes, the electric discharges leave indistinct and elongated traces, which, when the speed amounts to 300 words or over, run into one another and make a continuous line. This effect is due to the property which all electrified bodies have of inducing electricity in neighboring bodies. The earth, reacting on the line wire suspended above it, induces in it what is called an extra current, both on closing and breaking the circuit. On first closing the circuit the extra current runs in the contrary direction to the primary, and retards and weakens its action, so that, if suffered to record itself, it would do so by a mark like this:  the long after-part being caused partly by the accumulated electricity and partly by the second extra current which is in the same direction with the primary one.

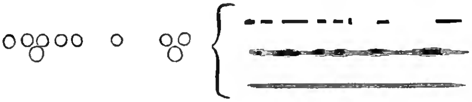

FIG. 4.

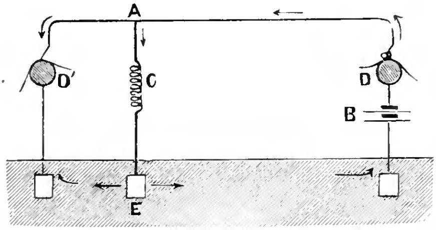

FIG. 5.

By Mr. Edison's plan the evil is made to cure itself. He simply interposes another wire with a coil, shown at *A C E*, (Fig. 5). This divides the current, one part of which is again subdivided on reaching the earth, and a moiety of it ascending the ground-line at *D'* counteracts the first weak installment of the other. Then, as each turn of the coil, *C*, acts the part of the earth on the turn next it, the whole sets up another powerful extra current, which at first forces the full strength of the main current through the recording instrument, and ultimately counteracts the accumulated electricity and the second extra current due to the earth. In practice, several such lines are used, and magnets, which are preferable, instead of coils. This occasions a great loss of electricity, but the sensitiveness of the receiving apparatus is such that less than one-fourth of the total strength of the current is sufficient to give a good record.

The chemical used by Bain in his sensitized paper was ferrocyanide of potassium, which, with the oxide from the iron pen and an extra equivalent of oxygen, forms Prussian blue. The oxygen of the air, it has been found, protracts this action, and thus arises another source of confusion, which is not affected by the device just described. A preferable combination, requiring only the protoxide of iron, which is formed immediately by the electricity, is used in the American system.

One of the most curious of the recent discoveries respecting the chemical action of electricity is that of its usefulness, under certain circumstances, as a lubricator. During Mr. Edison's experiments on the automatic telegraph he perceived that, when using a paper soaked in a certain solution, the pen was apt to slip whenever a discharge occurred. This effect was found to be so marked that a person drawing a strip of metal along the paper—leaning rather heavily on it—finds his hand obliged to move in a succession of jerks when signals are sent by a current powerful enough to overcome the resistance of his body. On this principle, Mr. Edison has constructed a little instrument in which a style is kept pressed against the paper by springs so as to make a continuous indentation, except when the current is passing. Its record is, therefore, the reverse of that of a Morse register; but the "electromotograph," as it is called, differs also from the "Morse" in being the most sensitive recording instrument known.

Still another of Mr. Edison's inventions is the quadruplex telegraph, the principal aim of which is, not to augment the speed of signaling, but, like the duplex, to allow of several persons using the same wire at one time. In fact, the arrangement may be used as a duplex telegraph, if required, so that the wire is by it made susceptible of either double or quadruple employ.

The instruments used are modifications of those of the Morse system. The "key" has already been shown in Fig. 2, and the changes made to adapt it to the uses of the quadruplex telegraph may be understood from Fig. 5. The essential part of the receiving instrument is an electro-magnet, which is shown in Fig. 2, and consists of a bent bar of soft iron, surrounded at each end by a coil of wire connected with the wire of the line. The current, passing through these coils, communicates to the iron core magnetic properties, and enables it to attract another piece of iron or steel called its armature; but, when the current ceases, the magnetism ceases also, and a spring—too weak to neutralize it—draws back the armature. It is shown in section at *M*, in Fig. 6. When the armature and the lever carrying it are discarded, and instead of them a jointed tongue of steel, as at *PM*, is inserted between the poles of the magnet, it will be unaffected by the current except when a change occurs in its direction. It is then called a polarized magnet. Its use will be explained a little further on. One of the keys, *K*, in the diagram, is provided with a spring, which is in contact with the metal of the key when this latter is in its normal position, and maintains across the key a circuit including a portion of the battery *b′*. But when the key is depressed the spring comes in contact with a screw, to which another circuit is connected, applying the full strength of the battery to the line. The circuit across the key is never broken, because the spring remains in contact with the arm of the key until it begins to press against the screw. This key works the magnet *M*, which has its retractile spring so adjusted as to be overcome only by the full intensity of the current when the key is down. The other key, *K′*, is for changing the direction of the current, and working the polarized magnet, *PM*. Its construction is such that, when not in use, one pole of the battery, the positive, for example, is in connection with the line, and the negative with the earth, necessitating the passage of the current through the line in the first place; but when the key is touched the negative pole is connected "to line" and the positive to earth, reversing the direction of the current. These reversals of direction operate, as has been said, the polarized magnet *PM*.

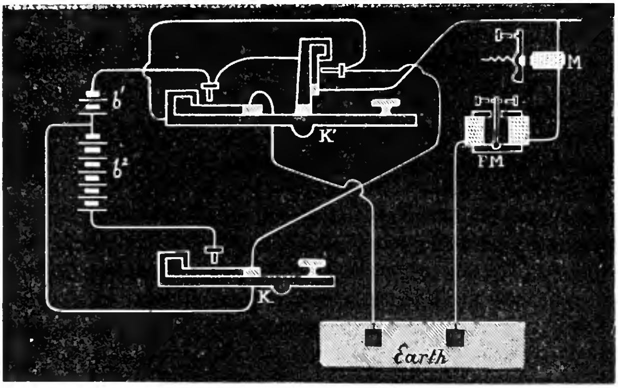

FIG. 6.

To revert to the illustration we made use of in describing the duplex, let the reader picture to himself a water-course in which both the direction and the volume of the current can be changed at pleasure. He can suppose, in addition to the water-wheels before figured, and which will indicate the force of the stream, a pair of hinged valves or gates, which, whether the current be strong or weak, will be moved only by a change in its direction. The former will represent the ordinary magnets, and the latter the polarized magnets.

It is plain that, so far, this is only another form of duplex, sending two messages in the same direction at once. To make it a quadruplex telegraph it is necessary, in the first place, to add to it Stearns's duplex, or a contrivance similar to it. Even then a dead-lock would happen when the currents sent from each end of the line should be of the same intensity, and opposite in direction; that is, when all eight operators were working together. To remedy this, extra batteries are introduced, which are neutralized by part of the current in the main circuit, when that is in a working condition, but are set free to work the instruments when the currents in the main circuit destroy one another. In the diagram the extra batteries, etc., have been omitted, as also the transmitting apparatus of one station and the recording instruments of the other.

Although not strictly coming under its title, because belonging, as yet, rather to the future, this article would hardly be complete without some reference to a scheme of multiplex telegraphy which promises results of the greatest importance. The ingenious magnetic apparatus used by Prof. Helmholtz, of Berlin, in his researches in acoustics, was too suggestive not to have inspired more than one inventor with the idea of turning it to account in telegraphy. Accordingly, several, both here and in Europe, have been trying to realize it, and it is likely that the magnetically-excited tuning-forks, or the sonorous steel bars which may be substituted for them, will shortly be heard in every telegraph-office. There seems, so far, to be no ascertained limit to the number of distinct musical notes which may be propagated on a single wire at one time; and, when that limit is found, it is likely that it may be doubled or quadrupled by means of the former systems. The reduction in the cost of erection and maintenance of wires which this will bring about will be an enormous saving to telegraph companies, especially to any new ones that may be formed, or to the Government, if it should undertake the control and extension of the service.

An interesting experiment of Sir Charles Wheatstone's on the transmission of sound through solid linear conductors has, perhaps, helped to suggest this approaching transformation of the telegraph. An account of it was published in 1831. A narrow wooden rod was attached at one end to the sounding-board of a piano, and, after passing through two empty rooms, was joined at the other end to a sounding-board alone. Any piece of music played on the piano was distinctly heard by means of the sounding-board in the distant room. And not the least confusion ensued from the crowding together, for a considerable distance, of the multitude of intricately-related vibrations in a rod having a section of but one square inch.

Prof. Helmholtz's apparatus consisted of a number of electro-magnets acting on tuning-forks pitched to particular notes. His object was so to combine those notes as to demonstrate the formation of certain harmonious sounds; but the object of the telegraph-inventors is the reverse of that, namely, to transmit them in the form of *electric* vibrations to a distance, and then—as in Wheatstone's experiment—to sift them out again to separate instruments. In most of the plans so far made public, a fixed steel bar takes the place of the tuning-fork, and therefore of the armature as well. When attracted by the magnet, on making a signal, it is of course set vibrating; and, at every forward vibratory movement, it closes the circuit and transmits an electric impulse. A number of such magnets, their sonorous armatures sending each a different number of pulsations in a second, may be working away at once, and the corresponding instruments at the other end of the line will be acted on only by those which suit their times of vibration. In other words, of the total number of electric charges sent into the line, only those will act on any particular magnet at the receiving end which suffice to cause in its armature the number of vibrations per second to which it was set. This, of course, is the same number which was sent by the transmitting instrument of the same pair. Practically, the different tones are not reproduced quite unmixed, every armature being capable of responding though in a less degree, to other notes than its own; so that the effect on the ear, at one of the receiving magnets, is like that of a number of persons talking together in different keys: some quite loudly; some in a lower tone; others in a whisper. To remedy this, different forms of resonators are being tried, adapted to swell the special sounds that should be heard.

The "electromotograph," described in connection with chemical telegraphs, is intended, by its inventor, to be used with some form of this acoustic system. Mr. Gray, of Chicago, another well-known telegraph-inventor, is also understood to have made considerable progress in this direction.

It is matter of reasonable pride to find, at the commencement of our second century, the names of Americans so prominently connected with all the great improvements in the art which owes so much to the labors of Morse and Henry.

# CONSCIENCE IN ANIMALS.

By G. J. ROMANES, M. A., F. L. S.

AMONG several other topics which are dealt with in an interesting article entitled "Animal Depravity" that appeared in the *Quarterly Journal of Science* for October last, the writer alludes to the question as to whether or not the rudiments of a moral sense are discernible in animals. This question I consider to be of so much importance from a psychological point of view that, although a great deal of observation which I have directed toward its enlightenment has hitherto yielded but small results, I am tempted to publish the latter, such as they are, in the hope that, if they serve no better end, they may perhaps induce some other observers to bestow their attention upon this very interesting subject.

I may first briefly state what I conceive to be the theoretical standing of the subject. At the present day, when the general theory of evolution is accepted by all save the ignorant or the prejudiced, the antecedent probability is overwhelming that our moral sense, like all our other psychological faculties, has been evolved. The question as to the *causes* of its evolution has been discussed in the "Descent of Man," and this with all the breadth of thought and force of fact so characteristic of the writings which have exerted an influence upon human thought more profound than has been exerted by the writings of any other single man—not even excepting Aristotle in philosophy or Newton in science. Mr. Herbert Spencer, also, has treated of this subject, and, if his wonderful "programme" is ever destined to attain completion, we may expect copious results when his great powers are brought to bear upon the "Principles of Morality." Meanwhile, however, we have ample evidence to render it highly probable that at any rate the leading causes in the development of our moral sense have had their origin in the social instincts. Indeed, to any one who impartially considers this evidence in the light of the general theory of evolution, it must appear wellnigh incredible that so considerable a body of proof can ever admit of being overcome. Nor is this all. Not only is it true that so much success has attended Mr. Darwin's method of determining synthetically the causes which have been instrumental in evolving the moral sense,[1] but, long before any scientific theory of evolution had been given to the world, our great logician—following in the track of Hume (whose part in this matter has not, I think, been sufficiently appreciated), Bentham, and others—proved

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[1] I willingly indorse the just tribute recently paid to this part of Mr. Darwin's work by Prof. Clifford: "To my mind the simplest and clearest and most profound philosophy that was ever written upon this subject is to be found in chapters ii. and iii. of Mr. Darwin's 'Descent of Man.'"—*Fortnightly Review*, p. 794.

analytically, to the satisfaction of all competent and impartial thinkers, that the moral sense is rooted in "the greatest amount of happiness principle" as its sustaining source. In other words, John Stuart Mill, by examining conscience as he found it to exist in man, showed that it depends upon the very principle upon which it ought to depend, supposing Mr. Darwin's theory—elaborated, be it remembered, without any reference to Mr. Mill's analysis, and arrived at by a totally different line of inquiry—concerning the causes of its evolution to be the true one.

Stronger evidence, then, as to the physical causes whose operation has brought human conscience into being, we could scarcely expect, in the present condition of physical science, to possess. It is unnecessary, however, in this place to enter into the details of this evidence, as almost every educated person must be more or less acquainted with them. I shall therefore pass on to the next point which concerns us—namely, supposing the causes of our moral sense to have had their origin in the social instincts, where and to what extent should we expect to find indications of an incipient moral sense in animals? First, then, what do we mean by conscience? We mean that faculty of our minds which renders possible remorse or satisfaction for past conduct, which has been respectively injurious or beneficial to others.[1] This, at least, is what I conceive conscience to be in its last resort. No doubt, as we find it in actual operation, the faculty in question has reference to ideas of a higher abstraction than that of the fellow-man whom we have injured or benefited. In most cases the moral sense has reference to the volitions of a Deity, and in others to the human race considered as a whole. But, if the moral sense has been developed in the way here supposed, its root-principle must be that which has reference to ideas of no higher abstraction than those of parent, neighbor, or tribe. Now, even in this its most rudimentary phase of development, conscience presupposes a comparatively high order of intelligence as the prime condition of its possibility. For not only does the faculty as above defined require a good *memory* as a condition essential to its existence, but—what is of much greater importance—it also requires the power of *reflecting upon past conduct;* and this, it is needless to say, appears to be a much rarer quality in the psychology of animals than is mere memory.

Thus, if Mr. Darwin's theory concerning the origin and development of the moral sense is true, we should not expect to find any indications of this faculty in any animals that are too low in the psychological scale to be capable of reflecting upon their past conduct. Whether this limitation does not exclude all animals whatever is a question with which I am not here concerned. I merely assert that, if the theory in question is the true one, and if no animals are capable

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[1] For reasons which may easily be gathered from the next succeeding sentences, I omit *conscientious* ideas of what is due to *self.*

of reflecting upon their past conduct, then no animals can possess a moral sense, properly so called. And from this, of course, it follows that, if any animals can be shown to possess a moral sense, they are thereby also shown to be capable of reflecting upon their past conduct.

Again, if Mr. Darwin's theory concerning the origin and development of the moral sense is true, it is self-evident that we should not expect to find any indications of this faculty in animals that are either unsocial or unsympathetic. Supposing the theory true, therefore, our search for animals in which we may expect to find any indications of a moral sense is thus seen to be very restricted in its range: we can only expect to find such indications in animals that are highly intelligent, social, and sympathetic. Since, by the hypothesis, conscience requires a comparatively rare collocation of conditions for its development, we must expect to find it a comparatively rare product.

Lastly, as it is quite certain that no animal is capable of reflecting upon past conduct in any high degree, and as we have just seen that the moral sense depends upon the faculty of so reflecting, it follows that we cannot expect to find any animal in which the moral sense attains any high degree of development.

We are now in a position to draw some important distinctions. There are several instincts and feelings which, when expressed in outward action, more or less simulate conscience (so to speak), but which it would be erroneous to call by that name. For instance, the maternal instinct, although it leads in many cases to severe and sustained self-denial for the benefit of the offspring, is nevertheless clearly distinct from conscience. The mother in tending her young does so in obedience to an inherited instinct, and not from any fear of subsequent self-reproach if she leaves her family to perish. She follows the maternal instinct, so long as it continues in operation, just as she would follow any other instinct; and it is, as it were, a mere accident of the case that in this particular instance the course of action which the instinct prompts is a course of action which is conducive to the welfare of others. An illustration will render this distinction more clear. In his chapter on the "Moral Sense," Mr. Darwin alludes to the conflict of instincts which sometimes occurs in swallows when the migratory season overtakes a late brood of young birds; at such times "swallows, house-martins, and swifts, frequently desert their tender young, leaving them to perish miserably in their nests." And further on he remarks: "When arrived at the end of their long journey, and the migratory instinct has ceased to act, what an agony of remorse the bird would feel if, from being endowed with great mental activity, she could not prevent the image constantly passing through her mind of her young ones perishing in the bleak north from cold and hunger!" In other words, if we could suppose the mother-bird under such circumstances to be capable of *reflecting upon her past conduct*, and, as a consequence, suffering an "agony of remorse," then the bird might properly be said to be *conscience-stricken*. And if we could suppose the bird, while still brooding over her young ones, to foresee the agony of remorse she would subsequently feel if she now yields to the stronger instinct by deserting her young, then the bird might properly be said to be acting *conscientiously*.

Again, mere fear of punishment must not be confused with conscience—it being of the essence of conscientious action that it should be prompted by feelings wholly distinct from fear of retaliation by the object of injury, whether by way of punishment or revenge. Conscience must be capable of effecting its own punishment if violated; otherwise the principle of action, whatever it may be, must be called by some other name.[1]

It is evident that conscience, as we find it in ourselves, is distinct from love of approbation and fear of disapprobation. Nevertheless, if our hypothesis concerning the development of the moral sense is the true one, we should expect that during the early phases of that development love of approbation and fear of disapprobation should have played a large part in the formation of conscience. For although, by the hypothesis, it is sympathy and not self-love that constitutes the seat of the moral sense, still the particular manifestations of self-love with which we are now concerned—viz., desire of approbation and dislike of the reverse—would clearly be impossible but for the presence of sympathy. "Mr. Bain has clearly shown that the love of praise, and the strong feeling of glory, and the still stronger horror of scorn and infamy, 'are due to the workings of sympathy.'"[2] I think, therefore, that in testing—by observations upon the lower animals—the truth of Mr. Darwin's theory concerning the genesis of conscience, it would be no valid objection to any satisfactory instances of conscientious action in an animal to say that such action is partly due to a desire of praise or a fear of blame. This would be no valid objection, because, in the first place, it would in most cases be impossible to say how far the implication is true—how far the animal may have acted from pure sympathy or regard for the feelings of others, and how far from an admixture of sympathy with self-love; and in the next place, even if the implication be conceded wholly true, it would not tend to disprove the theory in question. If an animal's sympathies are so powerful that, even after being reflected through self-love, they still retain force enough to prompt a course of action which is in direct opposition to the more immediate dictates of self-love, then the sympathies of such an animal are hereby proved to be sufficiently exalted to

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[1] Of course I recognize fear of punishment as an important factor in the *original constitution* of the moral sentiment; but, for reasons stated at the end of this article, we must, when treating of animal psychology, eliminate this factor when *conscience has become sufficiently developed to be "a law to itself."*

[2] "Descent of Man," p. 109 (1874). "Mental and Moral Science," p. 254 (1868).

constitute the beginnings of a conscience, supposing the theory which we are testing to be the true one.

Similarly, there is an obvious distinction in ourselves between injured conscience and injured pride. But, if conscience has been developed in the way here supposed, it follows that in the rudimentary stages of such development the distinction in question cannot be so well defined. Pride presupposes consideration for the opinion of others, and this in turn—as we have just seen—presupposes sympathy, which is the foundation-stone of conscience. Now, it is certain that long before we reach, in the ascending scale of animal psychology, intellectual faculties sufficiently exalted to admit even of our suspecting the presence of an incipient moral sense, we can perceive abundant indications of the presence of pride. And, forasmuch as animals that are high in the psychological scale frequently exhibit a very profound appreciation of their own dignity, we may pretty safely conclude that in no case can we expect to find indications of a moral sense in an animal without a greater or less admixture of pride.

I will now sum up this rather tedious preamble: From Mr. Darwin's theory concerning the development of conscience, it appears to follow that the presence of this faculty in animals must be restricted—if it occurs at all—to those which are intelligent enough to be capable in some degree of reflecting upon past conduct, and which likewise possess social and sympathetic instincts. From the first of these conditions it follows, supposing Mr. Darwin's theory true, that in the case of no animal should we expect to find the moral sense developed in any other than a low degree.

There is no reason to suppose any mere *instinct* (such as the maternal) due to conscience; for an instinct acquired by inheritance is obeyed blindly, in order to avoid the uncomfortable sensation which ensues in a direct manner if it is not so obeyed; whereas conscience enforces obedience only through a process of reflection;[1] the uncomfortable sensation which non-obedience entails in this case being only brought about in an indirect manner through the agency of representative thought.

Although conscience in man is independent of, or distinct from, love of approbation, fear of reproach, and sense of pride, there is no reason why we should suppose conscience in its rudimentary forms to be independent of these passions. On the contrary, I think we should expect a rudimentary form of conscience to be more or less amalgamated with such passions; for, long before the faculty in question has attained the highly-differentiated state in which we find it to be present in ourselves, it must (by the hypothesis) have passed through in-

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[1] i. e., *originally:* when once the *habit* of yielding obedience to conscience has been acquired, it becomes itself of the nature of an instinct—neglect to practise this habit giving rise immediately, or without any process of reflection, to an uncomfortable state of the mind.

numerable states of lesser differentiation in which its existence was presumably more and more bound up with that of those more primary social instincts from which it first derived its origin. To us conscience means a massive consolidation of innumerable experiences, inherited and acquired, of remorse following one class of actions and gratification their opposites; and this massive body of experience has reference to ideas of an abstraction so high as to extend far beyond the individual, or even the community, which our actions primarily affect. No wonder, therefore, that, when any course of action is being contemplated, conscience asserts her voice within us as a voice of supreme authority, commanding us to look beyond all immediate issues, inclinations, and even sympathies, to those great *principles* of action which the united experience of mankind has proved to be best for the individual to follow in all his attempts to promote the happiness or to alleviate the misery of his race. But with animals, of course, the case is different. They start with a very small allowance of hereditary experience in the respects we are considering; they have very few opportunities of adding to those experiences themselves; they probably have no powers of forming abstract ideas; and so their moral sense, rudimentary in its nature, can never be exercised with reference to anything other than concrete objects—relation, companion, or herd.

We may now proceed to answer the question already propounded, namely: Supposing Mr. Darwin's theory concerning the origin of the moral sense to be true, where among animals should we expect to find indications of such a sense? I think reflection will show that the three essential conditions to the presence of a moral sense are only complied with among animals in the case of three groups—namely, dogs, elephants, and monkeys. I need not say anything about the *intelligence* or the *sociability* of these animals, for it is proverbial that there are no animals so intelligent or more social. It is necessary, however, to say a few words about sympathy.

In the case of dogs sympathy exists in an extraordinary degree. I have myself seen the life of a terrier saved by another dog which staid in the same house with him, and with which he had always lived in a state of bitter enmity. Yet, when the terrier was one day attacked by a large dog, which shook him by the back, and would certainly have killed him, his habitual enemy rushed to the rescue, and, after saving the terrier, had great difficulty in getting away himself.

With regard to elephants, I may quote the well-known instance from the "Descent of Man:" "Dr. Hooker informs me that an elephant, which he was riding in India, became so deeply bogged that he remained stuck fast until next day, when he was extracted by means of ropes. Under such circumstances elephants seize with their trunks any object, dead or alive, to place under their knees, to prevent their sinking deeper in the mud; and the driver was dreadfully afraid lest the animal should have seized Dr. Hooker and crushed him to death. But the driver himself, as Dr. Hooker was assured, ran no risk. This forbearance, under an emergency so dreadful for a heavy animal, is a wonderful proof of noble fidelity."[1]

Many cases of sympathy in monkeys might be given, but I shall confine myself to stating one which I myself witnessed at the Zoölogical Gardens.[2] A year or two ago, there was an Arabian baboon and an Anubis baboon confined in one cage, adjoining that which contained a dog-headed baboon. The Anubis baboon passed its hand through the wires of the partition, in order to purloin a nut which the large dog-headed baboon had left within reach—expressly, I believe, that it might act as a bait. The Anubis baboon very well knew the danger he ran, for he waited until his bulky neighbor had turned his back upon the nut with the appearance of having forgotten all about it. The dog-headed baboon, however, was all the time slyly looking round with the corner of his eye, and no sooner was the arm of his victim well within his cage than he sprang with astonishing rapidity and caught the retreating hand in his mouth. The cries of the Anubis baboon quickly brought the keeper to the rescue, when, by dint of a good deal of physical persuasion, the dog-headed baboon was induced to let go his hold. The Anubis baboon then retired to the middle of his cage, moaning piteously, and holding the injured hand against his chest while he rubbed it with the other one. The Arabian baboon now approached him from the top part of the cage, and, while making a soothing sound, very expressive of sympathy, folded the sufferer in its arms—exactly as a mother would her child under similar circumstances. It must be stated, also, that this expression of sympathy had a decidedly quieting effect upon the sufferer, his moans becoming less piteous so soon as he was enfolded in the arms of his comforter; and the manner in which he laid his cheek upon the bosom of his friend was as expressive as anything could be of sympathy appreciated. This really affecting spectacle lasted a considerable time, and while watching it I felt that, even had it stood alone, it would in itself have been sufficient to prove the essential identity of some of the noblest among human emotions with those of the lower animals.

If there is any validity in the foregoing antecedent reflections, all who have the opportunity should make a point of observing whether any indications of conscience are perceptible in monkeys, elephants, or intelligent dogs. My own opportunities of observation have been restricted to the last of these animals alone, so I shall conclude this article by giving some instances which appear to me very satisfactorily to prove that intelligent and sympathetic dogs possess the rudiments of a moral sense.

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[1] *See*, also, Hooker's "Himalayan Journal," vol. ii., p. 333 (1854).

[2] I hope it is unnecessary to say that, in detailing this and all the subsequent incidents, I carefully avoid exaggeration or embellishment of any kind.

I have a setter just now which has been made a pet of since a puppy. As he has a very fine nose, and is at liberty to go wherever he pleases, he often finds bits of food which he very well knows he has no right to take. If the food he finds happens to be of a dainty description, his conscientious scruples are overcome by the temptations of appetite; but, if the food should be of a less palatable kind, he generally carries it to me in order to obtain my permission to eat it. Now, as no one ever beats or even scolds this dog for stealing, his only object in thus asking permission to eat what he finds must be that of quieting his conscience. It should be added that when he brings stolen property to me it does not always follow that he is allowed to keep it.

This same animal, when I am out shooting with him, sometimes of course flushes birds. When he does so he immediately comes to me in a straight line, carrying his head and tail very low, as if to ask for pardon. Although I speak reproachfully to him on such occasions, I scarcely ever chastise him; so it cannot be fear that prompts this demeanor.

One other curious fact may here be mentioned about this dog. Although naturally a very vivacious animal, and, when out for a walk with myself or any other young person, perpetually ranging about in search of game, yet if taken out for a walk by an elderly person he keeps close to heel all the time—pacing along with a slow step and sedate manner, as different as possible from that which is natural to him. This curious behavior is quite spontaneous on his part, and appears to rise from his sense of the respect that is due to age.

The writer of the article on "Animal Depravity" makes the following quotation from an article of mine in *Nature* (vol. xii., page 66): "The terrier used to be very fond of catching flies upon the window-panes, and if ridiculed when unsuccessful was evidently much annoyed. On one occasion, in order to see what he would do, I purposely laughed immoderately every time he failed. It so happened that he did so several times in succession—partly, I believe, in consequence of my laughing—and eventually he became so distressed that he positively *pretended* to catch the fly, going through all the appropriate actions with his lips and tongue, and afterward rubbing the ground with his neck as if to kill the victim; he then looked up at me with a triumphant air of success. So well was the whole process simulated that I should have been quite deceived, had I not seen that the fly was still upon the window. Accordingly, I drew his attention to this fact, as well as to the absence of anything upon the floor; and, when he saw that his hypocrisy had been detected, he slunk away under some furniture, evidently very much ashamed of himself."

Upon this case the author of the article on "Animal Depravity" very properly observes: "This last point is most significant, fully overturning the vulgar notion of the absence of moral life in brutes, and of their total want of conscience." I think this observation is warranted by the facts, for although I have heard it objected that the feeling displayed by the terrier in this case was that of wounded pride rather than of wounded conscience, still, from what has been previously said concerning this distinction in the case of animals, it will be seen that in this instance it is not easy to draw the line between these two sentiments.

The following instances, however, all of which occurred with the terrier just mentioned, are free from this difficulty:

For a long time this terrier was the only canine pet I had. One day, however, I brought home a large dog, and chained him up outside. The jealousy of the terrier toward the new-comer was extreme. Indeed, I never before knew that jealousy in an animal could arrive at such a pitch; but, as it would occupy too much space to enter into details, it will be enough to say that I really think nothing that could have befallen this terrier would have pleased him so much as would any happy accident by which he might get well rid of his rival. Well, a few nights after the new dog had arrived, the terrier was, as usual, sleeping in my bedroom. About one o'clock in the morning he began to bark and scream very loudly, and, upon my waking up and telling him to be quiet, he ran between the bed and the window in a most excited manner, jumping on and off the toilet-table after each journey, as much as to say: "Get up quickly; you have no idea of what shocking things are going on outside!" Accordingly, I got up, and was surprised to see the large dog careering down the road; he had broken loose, and, being wild with fear at finding himself alone in a strange place, was running he knew not whither. Of course I went out as soon as possible, and after about half an hour's work succeeded in capturing the runaway. I then brought him into the house and chained him up in the hall; after which I fed and caressed him with the view of restoring his peace of mind. During all this time the terrier had remained in my bedroom, and, although he heard the feeding and caressing process going on down-stairs, this was the only time I ever knew him fail to attack the large dog when it was taken into the house. Upon my reëntering the bedroom, and before I said anything, the terrier met me with certain indescribable grinnings and prancings, which he always used to perform when conscious of having been a particularly good dog. Now, I consider the whole of this episode a very remarkable instance in an animal of action prompted by a sense of *duty*. No other motive than the voice of conscience can here be assigned for what the terrier did; even his strong jealousy of the large dog gave way before the yet stronger dread he had of the remorse he knew he should have to suffer, if next day he saw me distressed at a loss which it had been in his power to prevent. What makes the case more striking is, that this was the only occasion during the many years he slept in my bedroom that the terrier disturbed me in the night-time. Indeed, the scrupulous care with which he avoided making the least noise while I was asleep, or pretending to be asleep, was quite touching, even the sight of a cat outside, which at any other time rendered him frantic, only causing him to tremble violently with suppressed emotion when he had reason to suppose that I was not awake. If I overslept myself, however, he used to jump upon the bed and push my shoulder gently with his paw.

The following instance is likewise very instructive: I must premise that the terrier in question far surpassed any animal or human being I ever knew in the keen sensitiveness of his feelings, and that he was never beaten in his life.[1] Well, one day he was shut up in a room by himself, while everybody, in the house where he was, went out. Seeing his friends from the window as they departed, the terrier appears to have been overcome by a paroxysm of rage; for when I returned I found that he had torn all the bottoms of the window-curtains to shreds. When I first opened the door he jumped about as dogs in general do under similar circumstances, having apparently forgotten, in his joy at seeing me, the damage he had done. But when, without speaking, I picked up one of the torn shreds of the curtains, the terrier gave a howl, and, rushing out of the room, ran up-stairs screaming as loudly as he was able. The only interpretation I can assign to this conduct is, that, his former fit of passion having subsided, the dog was sorry at having done what he knew would annoy me; and, not being able to endure in my presence the remorse of his smitten conscience, he ran to the farthest corner of the house crying *peccavi* in the language of his nature.

I could give several other cases of conscientious action on the part of this terrier, but, as the present article is already too long, I shall confine myself to giving but one other case. This, however, is the

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[1] A reproachful word or look from me, when it seemed to him that occasion required it, was enough to make this dog miserable for a whole day. I do not know what would have happened had I ventured to strike him; but once when I was away from home a friend used to take him out every day for a walk in the park. He always enjoyed his walks very much, and was now wholly dependent upon this gentleman for obtaining them. (He was once stolen in London through the complicity of my servants, and never after that would he go out by himself, or with any one he knew to be a servant.) Nevertheless, one day while he was amusing himself with another dog in the park, my friend, in order to persuade him to follow, struck him with a glove. The terrier looked up at his face with an astonished and indignant gaze, deliberately turned round, and trotted home. Next day he went out with my friend as before, but after he had gone a short distance he looked up at his face significantly, and again trotted home with a dignified air. After this my friend could never induce the terrier to go out with him again. It is remarkable, also, that this animal's sensitiveness was not only of a selfish kind, but extended itself in sympathy for others. Whenever he saw a man striking a dog, whether in the house or outside, near at hand or at a distance, he used to rush to the protection of his fellow, snarling and snapping in a most threatening way. Again, when driving with me in a dog-cart, he always used to seize the sleeve of my coat every time I touched the horse with the whip.

most unequivocal instance I have ever known of conscience being manifested by an animal.

I had had this dog for several years, and had never—even in his puppyhood—known him to steal. On the contrary, he used to make an excellent guard to protect property from other animals, servants, etc., even though these were his best friends.[1] Nevertheless, on one occasion he was very hungry, and, in the room where I was reading and he was sitting, there was, within easy reach, a savory mutton-chop. I was greatly surprised to see him stealthily remove this chop and take it under a sofa. However, I pretended not to observe what had occurred, and waited to see what would happen next. For fully a quarter of an hour this terrier remained under the sofa without making a sound, but doubtless enduring an agony of contending feelings. Eventually, however, conscience came off victorious, for, emerging from his place of concealment and carrying in his mouth the stolen chop, he came across the room and laid the tempting morsel at my feet. The moment he dropped the stolen property he bolted again under the sofa, and from this retreat no coaxing could charm him for several hours afterward. Moreover, when during that time he was spoken to or patted, he always turned away his head in a ludicrously conscience-stricken manner. Altogether I do not think it would be possible to imagine a more satisfactory exhibition of conscience by an animal than this; for it must be remembered, as already stated, that the particular animal in question was never beaten in its life.[2]—*Advance-sheets of the Quarterly Journal of Science.*

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[1] I have seen this dog escort a donkey which had baskets on its back filled with apples. Although the dog did not know that he was being observed by anybody, he did his duty with the utmost faithfulness; for, every time the donkey turned back its head to take an apple out of the baskets, the dog snapped at its nose; and such was his watchfulness that, although his companion was keenly desirous of tasting some of the fruit, he never allowed him to get a single apple during the half-hour they were left together. I have also seen this terrier protecting meat from other terriers (his sons), which lived in the same house with him, and with which he was on the very best of terms. More curious still, I have seen him seize my wristbands while they were being worn by a friend to whom I temporarily lent them.

[2] This latter point is most important, because, although the moral sentiment in its incipient stages undoubtedly depends in a large measure upon fear of punishment, still, in its more developed state, this sentiment is as undoubtedly independent of such fear (Cf. Bain, "Mental and Moral Science," pp. 456–459, 1875); and forasmuch as in our analysis of animal psychology we can be guided only by the study of outward actions, and forasmuch as the course of action prompted by direct fear of punishment will nearly always be identical with that prompted by true conscience, it is of the first importance to obtain cases such as the above, in which mere dread of punishment cannot even be suspected to have been the motive principle of action.

# AIR-GERMS AND SPONTANEOUS GENERATION.[1]

By P. SCHÜTZENBERGER.

THE question of the origin of ferments is intimately connected with that of spontaneous generation. In fact, from the time of Van Helmont and others, who, even in the seventeenth century, gave directions for the production of mice, frogs, eels, etc., the partisans of this mode of generation have, by the progress of the tendency to examine into the causes of things, been driven from the larger animals or plants visible to the naked eye, to the smallest living productions, which we can observe only by the aid of the microscope. But ferments are found among these inferior microscopic organisms. Redi, a member of the Academy of Cimento, showed that the worms in putrefied flesh, which were at first thought to be of spontaneous origin, are only the larvæ from the eggs of flies, and that all that was necessary, to prevent entirely the birth of these larvæ, was to surround the decomposing meat with fine gauze; he was the first to ascertain that parasitic animals are sexual and able to lay eggs.

The invention of the microscope, and the numerous observations by which it was followed, toward the end of the seventeenth, and the commencement of the eighteenth century, gave fresh impulse to the doctrine of spontaneous generation, which had lost all credit in questions concerning the origin of living beings of a higher order.

The question now was how to explain the origin of the various living productions, revealed by the microscope in infusions of vegetable and animal substances, among which no apparent symptom of sexual generation could then be found.

The subject was studied for the first time in a scientific manner by Needham, who published, in 1745, in London, a work on this subject. This observer did for infusoria what had already been done for the higher organisms. He protected, or rather endeavored to protect, vegetable or animal infusions from the action of germs, seeds, or any other agents of multiplication which could come from without. At the same time he destroyed by a physical agent, heat, the germs which might be supposed to exist beforehand in the liquid. Under these conditions, either living beings will be produced in the midst of the infusion, or none will be found there; in the former case, it must be admitted that these organisms are developed in the medium which is suitable to them, without the intervention of any germ; in the second, that the doctrine of spontaneous generation is false. In reality, the question can only be resolved in this manner, and all experimenters

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[1] Abridged from "Schützenberger on Fermentations," No. XX. of the "International Scientific Series."

who have entered upon it from Needham's time to the present day ought to have made use of it.

The serious and grave difficulty, on which, during this period, all discussions raised between heterogenists and panspermists have turned, is so to arrange the experiments as to remove every suspicion of the intervention of germs brought from without, or preëxisting in the liquid.

If the result is negative, if when all precautions that seem to be necessary have been taken, and all causes of error have been removed, there is no formation of infusoria, it will be difficult to raise any serious objection to the inevitable conclusion, provided that the methods employed for the purpose of eliminating the preëxisting germs are not of such a nature as to modify the medium, and to render it unfit for the development and the nutrition of living organisms. If, on the contrary, we still meet with the birth of living beings, the suspicion will always revive that the experiment has been badly performed, and that a contrary result would have been obtained by conducting it more carefully. The heterogenists, therefore, find themselves in a more disadvantageous situation than their opponents, and, notwithstanding the success which they may obtain, they will never convince them.

We think, therefore, that it is useless to give here a detailed account of their minute researches; they must be consulted in the original memoirs. *A single experiment which proves, by a negative result, that organic infusions, protected from germs from without, do not give birth to infusoria, is worth more, scientifically speaking, than ten experiments tending to establish the contrary opinion.*

If, therefore, we pass over the details of the fundamental experiments of the heterogenists, and speak of those the results of which are conformable to the ideas of the panspermists, it will not be in a spirit of partiality. We are convinced that the latter are the only ones free from all objections, the relative skill of the operators being disregarded, and considered as nothing in the estimate formed. We may, however, say that M. Pasteur's researches may serve as a model for all those who may wish to conduct investigations of this kind, whatever may be the preconceived opinion by which they are guided. By their precision, and the care taken to remove every source of error, they leave nothing to be desired.

As the results obtained by M. Pasteur lead him to deny spontaneous generation, his opponents must above all prove that he is mistaken, by adopting the same rigorous experimental conditions. Needham's experiments, which led him to admit and sustain the doctrine of spontaneous generation, consisted essentially in placing organic substances which were capable of decomposition, in vessels hermetically sealed, which were subsequently submitted to a high temperature, in order to destroy the preëxisting germs. The work of the English writer attracted great notice on account of the support of Buffon, whose ideas he upheld. Soon after began the great controversy between Needham and Spallanzani, who refuted, by experiment, the conclusions arrived at by Needham.

The controversy turned principally on this point: Spallanzani was not satisfied with heating the hermetically-sealed vessels containing the infusions, for several minutes, *merely the time which is required to cook a hen's-egg, and to destroy the germs*, as Needham expresses it, but he kept them for the space of an hour in boiling water. He then observed no production of infusoria. But, objects the English observer, from the manner in which he treated and put to the torture his nineteen vegetable infusions, it is evident that he not only much weakened, or perhaps totally destroyed, the *vegetative force* of the substances infused, but also entirely corrupted, by the exhalations and the odor of the fire, the small portion of air which remained in the empty part of his vessels. It is not, therefore, surprising that his infusions, thus treated, gave no signs of life. Such must necessarily have been the case. This idea, that the action of the temperature of boiling water destroys the vegetative force of infusions, is maintained even at the present day, and has served as an argument to the heterogenists; as they were unable to attack the material correctness of Pasteur's experiments, they did not accept the conclusions which he sought to derive from them.

We find also in the passage just cited, the necessity for the experiments made by Schwann and Helmholtz on calcined air, and for those of Schröder and F. Dusch, on strained air. The objection of a possible change in the air contained in the vial, under the influence of prolonged boiling, in presence of organic substances, was a serious one at the time that it was brought forward; it becomes more so, when we know that the air confined over preserved meats, prepared by Appert's process, contains no oxygen. It was, therefore, absolutely necessary to place the infusions in contact with air in a normal condition, after that boiling had deprived them of their preëxisting germs, avoiding at the same time any new germs brought by the air.

For this purpose, Dr. Schwann heated flasks containing the infusions, until the destruction of the germs was insured; but his flask was not closed: it communicated freely with the surrounding air by mean of a glass tube bent in the form of a U, and heated, in one part of its length, by means of a bath of fusible alloy. Under these conditions, the air may be renewed in the flasks, but the fresh atmospheric air admitted has undergone, like the infusion, the action of heat, which destroys the germs. Schwann's experiment was very decisive, as to broth made from meat; and the negative result (no development of infusoria) was quite satisfactory. But it was not the same with analogous trials on alcoholic fermentation, which gave contradictory results. Ure and Helmholtz repeated and multiplied these experiments with the same success.

To obviate the objection of a possible change by heat, in a mysterious and undefined principle, different from germs, but whose presence in the air was necessary to the production of infusoria, Schultze caused the renewed air to pass through energetic chemical reagents, such as concentrated sulphuric acid. He half filled a glass vessel with distilled water containing various animal and vegetable substances; then stopped the vessel with a cork through which passed two bent tubes, and exposed the apparatus thus arranged to the temperature of boiling water. Then, while the vapor was still escaping through the tubes, he adapted to each of them a Liebig's bulb apparatus, one containing concentrated sulphuric acid, and the other concentrated caustic potash. The high temperature must necessarily have destroyed every living thing, all the germs that might happen to be in the inside of the vessel, or of its appendages, and the communication from without was intercepted by the sulphuric acid on one side and the potassa on the other. Nevertheless, it was easy to renew, by aspiration at the end of the apparatus which contained the potassa, the air thus inclosed, and the fresh quantities of this fluid which were introduced could not carry with them any living germ, for they were forced to pass through a bath of concentrated sulphuric acid. M. Schultze placed the apparatus thus arranged at a well-lighted window, side by side with an open vessel, which contained an infusion of the same organic substances; then he was careful to renew the air in his apparatus several times a day for more than two months, and to examine with the microscope what took place in the infusion. The open vessel was soon found filled with vibrios and monads, to which were soon added polygastric infusoria of a larger size, and even rotifers; but by the most attentive observation he could not discover the least trace of infusoria, confervæ, or mildews, in the infusion contained in the apparatus.

The latest researches of Schröder and Von Dusch (1854–1859) tended to raise another objection, the possible change in a special principle in the air, by a reagent as energetic as sulphuric acid. Guided by the experiments of Loëwel, who ascertained that common air, when it had been previously filtered through cotton, was unfit to cause the crystallization of supersaturated solutions of sodium sulphate, they placed one of the tubes of Schultze's apparatus in communication with a tube 1.18 inch in diameter, and from 19.68 to 23.62 inches in length, filled with cotton-wool. The other tube was connected with an aspirator.

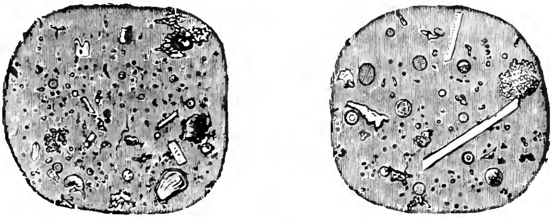
When the liquid, the interior of the flask, and the tubes, had been deprived of air by boiling, the apparatus was removed to its place, and the aspiration continued night and day. The two observers thus proved that meat, to which water had been added, the wort of beer, urine, starch, paste, and the various materials of milk taken separately, remained intact in the filtered air. On the contrary, milk, meat without water, and the yolk of egg, grew putrid as rapidly as in common air.

The result of these experiments is, that there are spontaneous decompositions of organic substances which require nothing but the presence of oxygen gas to cause them to commence; while others need, besides oxygen, the presence in the atmospheric air of *those unknown things*, which are destroyed by heat or sulphuric acid, or are retained by the cotton.

The two observers do not then decide on the nature of these things, and do not assert categorically that they are germs, and, in reality, nothing allows us to draw these conclusions.

M. Pasteur's experiments have advanced the question another step, by proving that they are really germs of ferments and infusoria, which are destroyed by heat, or arrested by the sulphuric acid or cotton in the experiments alluded to above.

M. Pasteur made a hole in a window-shutter, several metres above the ground, and through this he passed a glass tube .196 inch in diameter, and containing a plug of soluble cotton .39 inch in length, kept in its place by a spiral platinum wire. One of the ends of this tube passed into the street; the other communicated with a continuous aspirator. When the air had passed for a sufficient time, the plug of cotton, more or less soiled by the dust which it had intercepted, was placed in a small tube with the mixture of alcohol and ether, which dissolves gun-cotton. It was left for the space of a day. All the dust was deposited at the bottom of the tube, where it is easy to wash it by decantation, without any loss, if care is taken to separate each washing by an interval of repose of from twelve to twenty hours. The deposit, and the liquid which covers it, are put in a watch-glass together; after the evaporation of the alcohol, the remainder is placed in water, and examined with the microscope. M. Pasteur also made use of ordinary sulphuric acid in order to moisten the dust. This agent had the effect of separating the grains of starch and calcium carbonate, which are always found in greater or less quantities in deposits collected on the plug of cotton.



FIGS. 1 AND 2.—ORGANIC CORPUSCLES OF DUST, MIXED WITH AMORPHOUS PARTICLES.

Figs. 1 and 2 represent organic corpuscles, associated with amorphous particles, as seen through the microscope, under a power of 350 diameters; the liquid containing them was common sulphuric acid.

Fig. 1 applies to dust collected from the 25th to the 26th of June, 1860; Fig. 2 to dust from the very intense fog of January, 1861.

It was not enough to discover with the microscope organic particles mixed with amorphous substances, but it was necessary to prove that these particles really consisted of fertile germs, capable of producing the infusoria which are developed in such abundance in organic liquids exposed to the air. For this purpose, M. Pasteur arranged the experiment in the following manner:

Into a flask capable of containing from 15 to 18 cubic inches, he introduced 6 to 9 cubic inches of albuminous saccharine water, prepared in the following proportions:

Water, 100;
Sugar, 10;
Albuminoid and mineral matter from beer-yeast, .2 to .7.

The neck of the drawn-out neck-flask communicated with a platinum tube, as shown in Fig. 3. In this first stage of the experiment the T-shaped tube with three stopcocks is removed, and its place supplied by a simple India-rubber connecting-piece. The platinum tube is raised to a red heat by means of a small gas-furnace. The liquid is boiled for two or three minutes, and is then allowed to grow completely cold. It is filled with common air, at the ordinary pressure of the atmosphere, but which has been wholly exposed to a red heat; then the neck of the flask is hermetically sealed.

This, being thus prepared and detached, is placed in a stove at a constant temperature of about 86° Fahr.; it may be kept there for any length of time without the least change in the liquid which it contains. It preserves its limpidity, its smell, and its weak acid reaction; even a very slight absorption of oxygen is mainly to be observed. M. Pasteur affirms that he never had a single experiment, which was arranged as described above, which yielded a doubtful result; while water of yeast mixed with sugar, and boiled for two or three minutes, and then exposed to the air, was already in evident process of decomposition in a day or two, and was found to be filled with bacteria and vibrios, or covered with mucors. These experiments are directly opposed to those of Messrs. Pousset, Mantegazzo, Joly, and Musset.

It is therefore clearly proved that sweetened yeast-water, a liquid very liable to be decomposed by the contact of common air, may be preserved for years unaltered when it has been exposed to the action of calcined air, after having been allowed to boil for a few minutes (two or three).[1]

This being determined, M. Pasteur adapted, by means of an India-rubber tube, the closed point of his flask filled with sweetened yeast-

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[1] M. Pasteur has pointed out a cause of want of success, which has led many experimenters into error; by showing that the mercury of a mercurial trough is a complete receptacle for living organisms, and consequently that all experiments made with such a trough must necessarily induce a development of infusoria.

water, which had been kept for two or three months in a heated stove, without any development of organisms, to an apparatus arranged like that in Fig. 3.

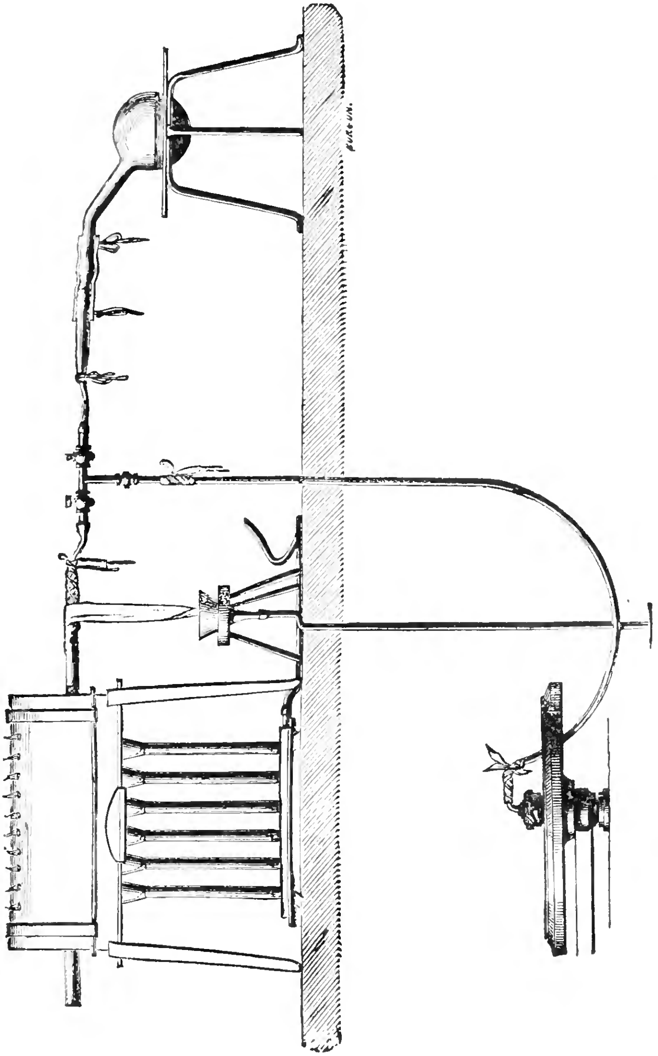

Fig. 3.—M. Pasteur's Apparatus for the Introduction of Calcined Air into Flasks containing Organic Infusions.

The pointed end of the flask passed into a strong glass tube .39 to 46 inch in its inner diameter, within which he had placed a piece of tube of small diameter, open at both ends, free to slip into the larger tube, and inclosing a portion of one of the small plugs of cotton loaded with dust. The larger glass tube is bound to a brass tube in form of a T, furnished with stopcocks, one of which communicates with the air-pump, another with the heated platinum tube, and the third with the flask, by means of the large tube which contains the smaller one with the cotton. These various parts are joined together by means of India-rubber.

The experiment is commenced by exhausting the air, after having closed the stopcock connected with the red-hot metallic tube. This being afterward opened, allows calcined air to enter the tubes slowly; this operation (exhaustion and readmission of calcined air) is repeated several times. The point of the flask is then broken off within the India-rubber, and the small tube containing the dust is allowed to slip into the flask, the neck of which is again sealed with the lamp. As an additional proof, and to obviate all objections, the same arrangements were made with similar flasks, prepared like the preceding, but with this difference that, instead of cotton charged with atmospheric dust, there was substituted a small piece of tube containing calcined asbestos (as an additional precaution, it had been ascertained that calcined asbestos, loaded with atmospheric dust, by the same means as the cotton, gave identical results).

The following are the observations obtained constantly by M. Pasteur:

In all the flasks, into which dust collected from the air was introduced—1. Organic productions began to make their appearance in the liquid after twenty-four, thirty-six, or forty-eight hours at the most. This was precisely the time necessary for the same phenomena to appear in sweetened yeast-water exposed to contact with the atmosphere.

2. The products observed are of the same kind as those which are seen to make their appearance in the liquid when left freely exposed to the air, such as mucors, common mucidines, torulacei, bacteria, and vibrios of the smallest species, the largest of which, the *Monas lens*, is only .000157 inch in diameter.

When the water of yeast is replaced by urine, the experiment being conducted exactly in the same manner, we always notice the absence of any change as long as atmospheric dust has not been introduced, while, with the addition of this, numerous organisms are developed, in every respect similar to those which appear and are developed in urine kept in the open air. If, on the contrary, the experiment be repeated with common milk, we may be sure that it will in every case curdle, and become putrid. We shall observe the birth of numerous vibrios of the same species, and bacteria, and the oxygen of the flask will disappear. M. Pasteur thinks that this result, so different from those observed in other liquids, arises only from the fact that milk contains germs of vibrios which resist the boiling heat of water. To prove this, he boiled milk, not at 212° Fahr., or at the usual pressure of the atmosphere, but at 230° Fahr., under a greater pressure, and he found that the flasks thus prepared, and hermetically sealed, could be kept for an indefinite time in the stove, without giving rise to the smallest production of mould or infusoria. The milk preserves its taste, its smell, and all its properties; and the atmosphere of the flask is only slightly modified in its composition. This difference between milk and urine, or sweetened yeast-water, must be attributed to the alkaline condition of the former medium, whereas the two others are acid. In fact, if we previously neutralize the acid of the sweetened yeast-water, by means of calcium carbonate, we obtain organisms under the same conditions of the experiment as those under which they were not before developed.

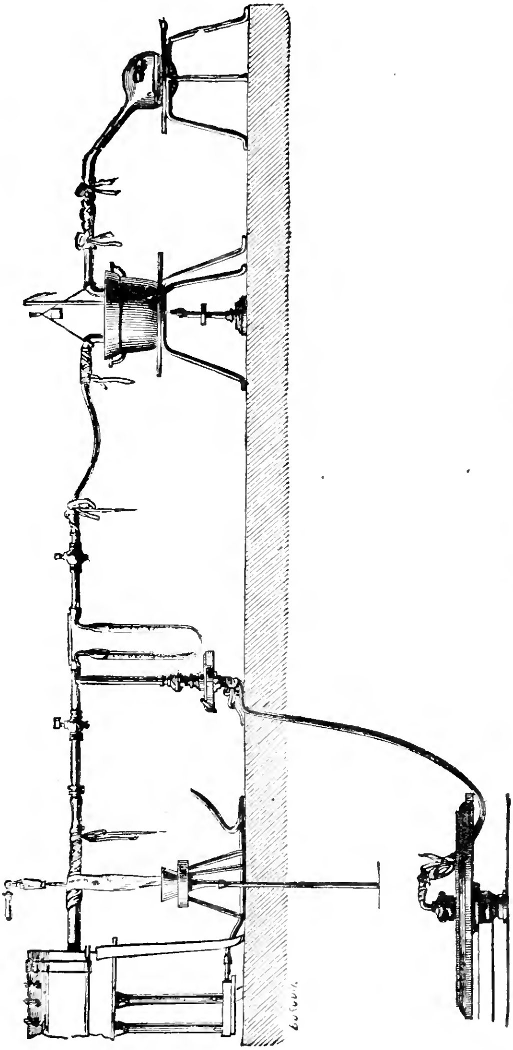

FIG. 4.—M. PASTEUR'S APPARATUS FOR STUDYING THE RESISTANCE OF GERMS AND SPORES TO TEMPERATURES MORE OR LESS ELEVATED.

These facts led M. Pasteur to make researches on the comparative action of temperature on the fecundity of the spores of the mucidines, and of the germs which exist suspended in the atmosphere.

The following is, in few words, the method followed by him: He passed a small portion of asbestos over the small heads of the moulds which he wished to study; he then placed this asbestos, covered with spores, in a small glass tube, which he introduced into a U-tube (Fig. 4) of larger diameter, in which the smaller tube could move freely; one of the extremities of the U-tube is joined by India-rubber to a metal tube in form of a T, with stopcocks. One of these cocks communicated with the air-pump, another with a red-hot platinum tube. The other extremity has an India-rubber tube which is connected with the flask into which the spores are to be introduced; this flask is hermetically sealed, and has been filled with calcined air, and suitable nutritious liquid previously raised to the boiling-point. Finally, the U-tube dips into a bath of oil, of common water, or salt-water, according to the temperature which we wish to attain. Between the U-tube and that of platinum, there is a drying-tube with sulphuric pumice-stone. When all the apparatus which precedes the platinum tube has been filled with calcined air, and the spores have been maintained at the desired temperature for a sufficient time, which may be varied at pleasure, the point of the flask is broken with a blow of a hammer, without unfastening the India-rubber connecting-pieces which attach the flask to the U-tube; then inclining to a proper angle this latter tube, when removed from its bath, the asbestos with its spores is slipped into the flask. The flask is then hermetically sealed, and is carried to the stove at 68° to 86° Fahr. The experiment with the dust from the air is also made in the same manner with asbestos.

Without any humidity, the fecundity of the spores of *Penecillium glaucum* is preserved up to 248° Fahr., and even a little above—257° Fahr. It is the same with the spores of the other common mucidines. At 266° Fahr., the power of developing or multiplying is destroyed in all of them. The limits are the same for the dust from the air.

In all these careful experiments, the most scrupulous precautions were taken to prevent the access of the slightest portion of common air. But, say the partisans of heterogenesis, if the smallest portion of common air develops organisms in any infusion whatever, it must necessarily be the case that, if these organisms are not spontaneously generated, there must be germs of a multitude of various productions in this portion of common air, however small it may be; and, if things were so, the ordinary air would be loaded with organic matter, which would form a thick mist in it.

M. Pasteur has shown that there is a great deal of exaggeration in the opinion that even the smallest quantity of air is sufficient to develop multitudes of organisms; that, on the contrary, there is not in the atmosphere a continuous cause of these so-called spontaneous generations; that it is always possible to procure, in any determined place, a limited quantity of common air, having undergone no kind of modification, whether physical or chemical, and nevertheless quite unsuited to set up any decomposing action in a liquid eminently putrescible. The method of experimenting is very simple. Into a flask of 15 to 18 cubic inches, 9 cubic inches of a liquid that has a tendency to decomposition are introduced; the neck of the flask is drawn out with the lamp, leaving the point open; then the liquid is boiled till the vapor escaping from the extremity has expelled all the air; at this moment the point of the flask is closed by the lamp, by means of a blowpipe, and it is allowed to grow cool. The flask then contains no air; if we break off the point in any particular place, the air reënters suddenly, carrying into it the germs held in suspension; it is again closed with the lamp, and kept in a stove at a temperature of 68° to 86° Fahr. In the generality of cases, organisms are developed; these organisms are even more varied than if the liquid were freely exposed to the air, which M. Pasteur explains by saying that, in this case, the germs in small number, in a limited volume of air, are not hindered in their development by germs in greater number or more precocious in their fecundity, which are able to occupy the space, and leave no room for them. But it is especially important to notice in the results obtained by this method, what frequently happens many times in each series of trials, that the liquid continues absolutely intact, however long it may have remained in the stove, as if it had been filled with calcined air. This phenomenon is the more striking, and shows itself in more marked proportions, when the air received into the flasks is taken from a greater height. Thus, among twenty flasks opened in the country, eight contained organic productions; out of twenty opened on the Jura, only five contained any; and out of twenty flasks opened at Montanvert, in a rather high wind, blowing from the deepest gorges of the "Glacier des Bois," only one was affected by any change.

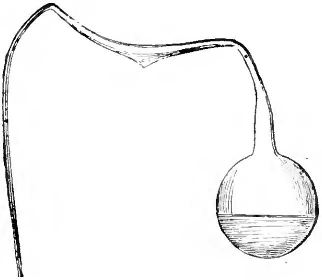

FIG. 28.—M. PASTEUR'S FLASK TO DEPRIVE THE AIR OF ITS GERMS.

We may also draw other conclusions from this series of observations. Since the putrescible liquid, which had been previously boiled, and which was contained in the flasks, was filled with organic productions in a great number of instances, after the introduction of a limited quantity of air, the genetic power of the infusions had not been destroyed by the material conditions of the experiments. Besides, this objection, which has been raised ever since the earliest controversies between the heterogenists and the panspermists, has been definitely answered by an experiment made by M. Pasteur; he received in a flask, exhausted and deprived of living germs by the momentary application of a sufficiently high temperature, some blood at the instant that it left the organism, and without allowing this liquid, which is so peculiarly putrescible, to come in contact with air. By permitting air deprived of germs, either by calcination or simple filtration, to enter the flask, and then hermetically sealing it, he found that the blood was preserved for an indefinite period intact, although it had not been exposed to heat.

M. Pasteur has also shown that air may be deprived of germs by its passage through a capillary tube bent upon itself. It is, therefore, sufficient, in most cases, to draw out the neck of the flask so as to form a very long, narrow tube, which is bent in several directions, as, for example, in Fig. 5. When the air originally contained in it has been expelled, and the preëxisting germs killed by prolonged boiling, the flask is allowed to cool slowly.

In closing our account of M. Pasteur's interesting memoir, in which heterogenesis was driven to its last intrenchments, we must add that this learned chemist endeavored to deprive his adversaries of one of their principal arguments. Experiments on spontaneous generation have always been conducted with vegetable or animal infusions; it was supposed by Needham, Buffon, and Pouchet, that organisms were only thus produced at the moment of expiring Nature, when the elements of the beings on which they are developed are entering into new chemical combinations, and are passing fully through the phenomena of fermentation or putrefaction.

In other words, albuminoid matters preserve in some degree a certain reserve of vitality, which would allow them to become organic by contact with oxygen, when the conditions of temperature and humidity are favorable. Starting with the idea that albuminoid substances are only aliments for the germs of infusoria, mucidines, or ferments, M. Pasteur has proved directly that organic substances may be replaced by those which are purely mineral or artificial, or, at least, by substances on which this imaginary vegetative force cannot be supposed to have any influence.

# SKETCH OF DR. AUSTIN FLINT, Jr.

THIS gentleman has won his scientific eminence in the field of physiology. Though but forty years of age, he has attained the highest rank in his chosen department as an experimental inquirer, teacher, and author—having published the most elaborate treatise upon the subject of physiology in the English language.

The name of Flint is now famous in the medical world through the celebrity of both father and son; but there is probably a factor of inherited genius in this line which goes to their making up, for they have come from a long race of doctors. This is the genetic line of the generations of medical Flints, so far as Americans will be interested to know it. They are descended from Thomas Flint, who came from Matlock, Derbyshire, England, in 1638, and settled in Concord, Massachusetts. Edward Flint, physician of Shrewsbury, Mass., was father of the great-grandfather of the subject of this sketch. The great-grandfather, Austin Flint, after whom the contemporary Flints are named, was a physician who died at Leicester, Massachusetts, in 1850, over ninety years of age. He served as a private soldier and afterward as a surgeon in the Revolutionary War. The grandfather of Austin, Jr., was Joseph Henshaw Flint, a distinguished surgeon of Northampton, Massachusetts, and afterward of Springfield, in the same State. His father is Austin Flint, now an eminent physician in New York City. He was born at Petersham, Massachusetts, in 1812, and graduated M. D. at Harvard, in 1833. He is a voluminous author and a distinguished practitioner.

Austin Flint, Jr., was born at Northampton, Massachusetts, March 28, 1836, and his parents removed to Buffalo, New York, in the same year. He was educated at private schools in that city, and, when fifteen, he spent a year in the Academy of Leicester, Massachusetts. He prepared for college at Buffalo, and entered Harvard University as Freshman in 1852. He left the university in 1853, and spent a year in the study of civil-engineering. He began the study of medicine in the spring of 1854 at Buffalo, and attended two courses of lectures at the medical department of the University of Louisville (1854–'55 and 1855–'56). His taste for physiology was early developed, and he made some experiments on living animals for Prof. Yandell, of the Louisville school, while he was a student there. His final course of lectures was taken at Jefferson Medical College, Philadelphia, in 1856–'57, and at the close of the course he graduated. His inaugural thesis on the "Phenomena of the Capillary Circulation" was honored with the recommendation to be published, and appeared in the *American Journal of Medical Sciences* in July, 1857. It was based upon numerous original experiments. He was editor for three years (1857–'60) of the Buffalo *Medical Journal*, which was founded by his father in 1846, and ultimately transferred to New York and merged in the *American Medical Monthly*.

In 1858 Dr. Flint was appointed one of the attending surgeons of the Buffalo City Hospital. The same year he became Professor of Physiology in the Medical School of Buffalo. In 1859 he removed with his father, and was appointed Professor of Physiology in the New York Medical College, delivering a course of lectures in 1859–'60. In 1860 he received the appointment of Professor of Physiology in the New Orleans School of Medicine, delivered a course of instructions in 1860–'61, and resigned the position at the breaking out of the war. While in New Orleans he experimented on alligators, and developed some important points with reference to the influence of the pneumogastric nerves upon the heart. He also made some experiments there upon the recurrent sensibility of the anterior roots of the spinal nerves. He was the first physiologist in this country to operate upon the spinal cord and the spinal nerves in living animals.

In the spring of 1861 Dr. Flint went to Europe, and studied several months with Charles Robin and Claude Bernard, with the former of whom he had close friendly and scientific relations, and maintained a frequent correspondence. Prof. Robin presented his memoir, "Sur une nouvelle fonction au foie" ("On a New Function of the Liver"), to the French Academy of Sciences for the Monthyon prize without the knowledge of the author. In 1863 Dr. Flint made some important experiments upon the blood, employing a new mode of analysis for its nitrogenized constituents. He was one of the founders of the Bellevue Hospital Medical College, in 1861, and has been from the first, as he still is, Professor of Physiology and Secretary and Treasurer of the Faculty. He was also for eight years Professor and Lecturer on Physiology in the Long Island College Hospital of Brooklyn.

In 1862 Dr. Flint made some remarkable observations on the excretory function of the liver, published in the *American Journal of the Medical Sciences*, in October, 1863; translated into French, and presented by Robin to the French Academy of Sciences for the "*Concours Monthyon*," and which received honorable mention and a recompense to the author of 1,500 francs in 1869. The important discovery put forth in this memoir was the production of cholesterine in the physiological wear of the brain and nervous tissue, the elimination of cholesterine by the liver, and its discharge in the form of stercorine in the fæces. It was established that the new substance (stercorine) results from the transformation of cholesterine in the fæces. The diseased condition caused by the retention of cholesterine in the blood (cholesteræmia) is now recognized as a very important pathological fact. Dr. Flint's laborious researches and interesting conclusions upon this subject have been lately confirmed in Germany by experiments in which cholesteræmia has been produced in animals by injection of cholesterine into the blood.

In 1867, at the request of the Commissioners of Public Charities and Correction of New York City, Dr. Flint reorganized the dietary system for the institutions under their charge, including Bellevue Hospital, Charity Hospital, Poorhouse, Workhouse, Penitentiary, etc., etc., making diet-tables for more than 10,000 persons. In 1871 he made observations upon Weston, the pedestrian, analyzing his food and secretions for fifteen days before, during, and after one of his great walking-exploits. These inquiries help to decide some important physiological questions.

In 1869 Dr. Flint published an elaborate review of the history of the discovery of the motor and sensory properties of the roots of the spinal nerves, in which the discovery was ascribed to Magendie instead of to Sir Charles Bell, who has generally been regarded as its author. This review, originally published in the *Journal of Psychological Medicine*, New York, in 1868, was translated into French, and published in Robin's *Journal de l'anatomie.* It produced such an impression that it was soon followed by the publication, in the English *Journal of Anatomy*, of the original paper of Charles Bell, "Idea of a New Anatomy of the Brain," which was privately printed (not published) in 1811. The original manuscript was furnished to the *Journal of Anatomy* by the widow of Sir Charles Bell. It was upon this paper that the claims of Charles Bell to the discovery were based; and, before its publication in the *Journal of Anatomy*, it had been entirely inaccessible.

Claude Bernard has been the eminent advocate of the theory that the liver is a sugar-producing organ; but observations upon this subject were discordant, and eminent physiologists contested Bernard's position. In 1869 Dr. Flint published, in the NEW YORK MEDICAL JOURNAL, a series of experiments upon the "glycogenic function of the liver," in which he endeavored to harmonize the various conflicting observations, and is considered by most physiologists to have settled the question.

In 1866 he announced the publication of the "Physiology of Man," a work in five volumes, of 500 pages each, and the last volume was issued in 1874. He printed a little work in 1870 on "Chemical Examinations of Urine in Disease," which went through several editions. He contributed the articles on gymnastics and pugilism to the "American Cyclopædia," was appointed Surgeon-General of the State of New York by Governor Tilden in 1874, and has recently published a voluminous "Text-book of Human Physiology." He has also written much for scientific periodicals and popular journals, and has been actively engaged in his duties as a physiological teacher.

# EDITOR'S TABLE.

## *THE NEW DEPARTURE AT THE CENTENNIAL EXHIBITION.*

We print the report of Commissioner Beckwith on the plan that has been adopted for the distribution of awards to exhibitors at the Philadelphia Exposition. In this matter the Centennial Commissioners have taken a new and very important step in advance of previous practice. The report is significant, as indicating a departure from the precedents of all former international exhibitions in a fundamental and perhaps the most important feature of their management. The system of gold medals and special prizes heretofore adopted has been abandoned, and articles of exhibition are to go upon their merits, as determined by competent judges from this country and abroad, and who will be responsible to the public for the opinions they give by signing their names to the published reports. This is a victory of honest good sense over former bad practices, which is most encouraging, and deserving of the heartiest commendation.

International expositions are new things in the world's experience. That is, they are new, as enormous extensions of local fairs and exhibitions which have been long in vogue. The primary idea was to bring all kinds of products together for public inspection and purchase. The show-element gradually became predominant, and the fair grew into an exhibition. The collection of rival commodities naturally led to competition, and this to committees of judgment or juries, which gave premiums for articles of the greatest excellence. Medals of gold, silver, and bronze, were assigned as testimonials of excellence in the articles approved. When the exhibitions grew into their great international proportions, this old method of awards was continued. But it was a very imperfect method, and its evils came out conspicuously in the great shows of London, Paris, and Vienna. The plan of granting graded medals is necessarily crude and inadequate; for, even if the awards are made upon the best judgment of the juries, they tell nothing, and are besides arbitrary and misleading. The differences among competing articles, in most cases, will not be as marked as the gradation of medals implies; so that their award will necessarily work injustice. There may be a score of products of the same kind, each, perhaps, with special merits, and none conspicuously preëminent; so that a gold medal awarded to one will greatly exaggerate its claims, and grossly wrong its rivals.

But this is not all, nor the worst. Medals become valuable and are eagerly sought because of the very injustice they work. To crown a single article, casts virtual reproach upon all its competitors; and hence the gold medal which exalts one thing and disparages all in rivalry with it is striven for with desperate eagerness by exhibitors on account of the commercial advantages that follow. The door is thus opened to every form of illegitimate influence that can be brought to bear upon the judges. The prizes to be won, being of enormous value, are fought for with such a reckless disregard of the means employed that men of integrity often quit the juries in disgust rather than be implicated in their corrupt proceedings. How great the strain must be, in many cases, is apparent when we reflect that, if the old system were in operation at the Philadelphia Exposition, there would probably be many exhibitors who could afford to pay, each a million dollars, to secure the gold medal that would place their articles in advance of all competitors. Nor is there anything in recent American experiences that would justify us in expecting an incorruptible administration of the duties of jurymen. Even where the distribution of medals is supplemented and corrected by written reports the results must be unsatisfactory, for it is of small moment to the public that the award has been qualified or contradicted in a printed document. The verdict of the medal itself will be held as the important and decisive thing. Mr. Beckwith, who has not only had experience of the old practice, but has carefully studied its general workings, points out in his report the inadequacy of the European jury system and the defectiveness of its results. Profiting by these failures, the Philadelphia plan has been organized to avoid them, and give us more valuable and trustworthy work.

The first purpose of such a collection of the products of art, science, and industry, as will be displayed in Philadelphia, undoubtedly is, that its objects may be seen and inspected by the public; yet the mere gratification of curiosity by staring at new and strange things is certainly its lowest advantage. Such exhibitions are only put to their best and proper use as means of public education, in which observers become inquirers, and get a knowledge of the true qualities and characters of the things exhibited. The value of the display will be in proportion to its intelligent appreciation, and the management of the affair must be judged by the efficiency and completeness of the means adopted to instruct the public in regard to it. To this end, the first step was to get rid of the misguiding and vicious system of medals, and then to secure capable men to furnish discriminating and responsible reports. It is well for the national honor and for wholesome public influence that the most efficient measures have been taken to put things for once upon their naked and sterling merits. The selection of a hundred able experts from abroad, with a hundred more to be furnished by this country as judges, who are to be paid their personal expenses, and who are committed by their reputations to give honest and competent verdicts on the intrinsic and comparative merits of objects exhibited—the reports to be published for the use of visitors at the earliest practicable moment—is a measure on the part of the commissioners at once so sensible and so just that it raises some perplexity as to how it has been brought about. The old method of proceeding is so rooted in universal usage, and so congenial with the fierce competitive spirit of American business, that we cannot for a moment suppose it has failed to make its best fight against this innovation. That it should have been beaten, and a greatly superior method adopted by the commissioners, is alike unexpected and a cause of devout gratitude.

But the policy initiated at Philadelphia has a still further significance. It is not merely a transient expedient in the tactics of a great show, but it declares a principle of wide and permanent application in society. Its adoption strikes a blow at the all-prevailing habit of offering prizes as artificial stimulants to effort, instead of making the intrinsic excellence of work and its intelligent appreciation the true impulse of exertion and enterprise. Competitions are inflamed in all directions by sordid and selfish temptations, but it is in education that the system of extrinsic rewards and factitious provocations is carried to the greatest extent, and leads to the most mischievous results. The practice of giving prizes in schools is vicious as substituting spurious and unworthy motives to exertion, where the very object is to form the character by bringing generous and ennobling incitements into habitual and controlling exercise. To beat an antagonist, and win a medal or a purse, is a vulgar and sordid inducement to study, and convicts the school that resorts to it of inefficiency in its legitimate and most essential work. It is, moreover, an injurious agency in education, as it is constantly used to stimulate students in false directions, and to the excessive cultivation of unimportant subjects. Our education is in a state of chaos in regard to the relative values of different kinds of knowledge. The waste of time and effort over comparatively worthless studies is something quite appalling, and it is everywhere aggravated by plying scholars with premiums for special attainments. Rich blockheads, with narrow notions and tenacious crotchets, smitten with the vanity of becoming public benefactors, go into the schools and found prizes and medals which set the students to racing in any direction which the whim or caprice of the donor may indicate. This evil is confessed, and has become so glaring that some institutions have wisely put a stop to such interference. But, as it is driven from the schools, it is taken up by outsiders, as we have seen in the intercollegiate contests that have lately come into vogue. Against this whole system the Philadelphia policy, as presented in Mr. Beckwith's report, is a tacit but powerful protest. To get things upon their real merits is a victory anywhere—to do this upon a great, unprecedented national occasion is a triumph—but there is no reason for adopting the principle in an exhibition of the products of manufacture that will not apply with increasing force to the management of educational establishments.

## *JUDGE DALY'S ADDRESS.*

It is not easy to deal with the annual presidential addresses of Charles P. Daly before the Geographical Society. They are so fresh, readable, and full of novel and instructive matter, that there is a temptation to reprint them bodily. We have formerly spoiled them by summarizing; this year we publish in full the introductory portion, in which he glances at the achievements of geographical explorers during the third quarter of the nineteenth century ending in 1875, and shows what the state of things was at the beginning of that age, and what it is now. The main portion of the address, however, is devoted to an account of the researches, discoveries, and geographical work, of the past year. We are tempted to make some further use of Judge Daly's labors, which may incite our readers to procure the full address and read it themselves. Beginning with what has been done in our own country, President Daly sums up the results of the various exploring expeditions and surveys undertaken or aided by the Government, in the great Western, Northwestern, and Southwestern tracts of the continent. The results are varied and interesting. In the prehistoric section, on the ancient inhabitants of America, the evidence has been much extended in regard to the life of the old race of mound-builders. In reference to the antiquity of man on this continent, it is remarked:

> "Prof. J. D. Whitney, from the remains found by him in California, is of the opinion that man existed there as long ago as the Tertiary period; that he was then the maker of instruments for grinding corn, as well as other implements of stone, and, as far as the examination of the imperfect skull which was found warrants a conclusion, that he was, at that remote period, the same anatomically that he is now. These discoveries of Prof. Whitney's go to show that man existed during the Glacial epoch, which is confirmed after seven years' examination of the deposits in the Victoria Cave, in England, and by recent discoveries in the inter-glacial coal-beds of Switzerland. The Glacial epoch is computed by Mr. Croll, in his recent work, to have ended about 80,000 years ago; and Mr. Croll is not only one of the best authorities, but the one whose estimate of the time is the lowest."

The work of arctic exploration continues to be vigorously pushed, and with promising results. A point of interest is, that the English and German geographers have abandoned the routes they formerly advocated, and have, with great unanimity, united in recommending that the English expedition which left last June, under the command of Captain Nares, should go through Smith's Sound, following up the track of Kane, Hayes, and Hall—the route that has been uniformly urged by the American Geographical Society as the best. At a crowded meeting of the Royal Geographical Society, at which the officers of the expedition and most of the distinguished arctic explorers were present, the American theory of polar approach was heartily commended:

> "Admiral Ommanny, formerly a prominent opponent of the route now adopted, also said that England must be grateful to her American cousins, who had cleared the way by successful operations through Smith Sound. When it is remembered that our early efforts in this direction were ignored, that the name of Grinnell Land, in Wellington Channel, was at first omitted upon English maps, and the name of a subsequent English explorer substituted, that our route by the way of Smith Sound received little support except from Admiral Sherard Osborn, Admiral Inglefield, and Mr. Clements R. Markham, this change of opinion and hearty recognition now are very gratifying, especially to our member, Dr. Hayes, the only one of our exploring commanders in the Arctic who is now alive."

To show that, in this boasted scientific age, geographical notions are still entertained as crude as those held five hundred years ago, Judge Daly gives an account of some of the theories that are still seriously advocated. One of these is described as follows:

> "About the year 1819, Captain J. C. Symmes, an officer of the regular Army of the United States, advanced a theory, to the propagation of which he devoted the remainder of his life, that the earth was hollow, was inhabited within, and had an opening at the pole, which became known throughout the country as 'Symmes's Hole.' He pressed the subject upon Congress, urged an expedition to the pole to test his theory, and a Russian gentleman is said to have offered to fit one out if Symmes would conduct it under the auspices of Russia, which the captain declined, on the ground that the honor of establishing the theory should belong to the United States. He went over the country, delivering lectures in support of this theory, in which he firmly believed to the day of his death. His son, now an old man, has revived it, and is advocating it, as his father did, by delivering public lectures. The father's theory was, that this hole or opening in the Arctic was about one thousand miles in diameter, and somewhat wider at the Antarctic; and now that we have reached within five hundred miles of the arctic pole, about half of the assumed diameter of the supposed hole, without any indication so far of its existence, the son believes that if Captain Hall had got several degrees farther north he would have found evidence of the truth of the theory.
>
> "Captain Hall startled us at the reception given to him and his officers by this Society, before the departure of the Polaris, by announcing publicly to us his belief in the existence of this hole, and of his determination to go in pursuit of it; a belief which, being an uneducated man, and but little acquainted with the geography of the Arctic, was firmly fixed in his mind. It was in pursuit of this supposed hole that he meant to attempt the passage to the pole by the way of Jones's Sound. I pointed out to him the impracticability of an attempt through Jones's Sound, and urged him to go as Kane and Hayes had done, by the way of Smith Sound, which course he ultimately adopted when advised to the same effect by Baron van Otten of the Swedish Expedition, whom he met during his voyage at Holsteinberg in Davis Strait.
>
> "In a letter put forth last February, by Mr. Symmes, he not only argues that the earth is hollow, but that it has as much inhabitable surface within as without. He imagines that the inside is inhabited by human beings who are the progenitors of the white race, now upon the outer surface, and that there are apertures at the poles four or more hundred miles in diameter. This recalls the belief as to the cause of the earth's motion in the middle ages, when it became apparent from the researches of Copernicus and Galileo that it revolved upon its axis, which accounted for the motion by supposing that the interior of the earth was hollow, and was the place to which the damned were condemned, who produced the motion by their continual attempts to climb up the inside of this hollow ball in their fruitless

efforts to get out. A woodcut representing this strange belief will be found in an old cosmography in our library."

Meteorological and earthquake disturbances of the past year are noted; and, with an account of the voyage of the Challenger and the important results attained by it, Judge Daly passes to the progress of geographical work in Europe, and gives an instructive account of the drainage of the Zuyder Zee now undertaken by the people of Holland, who have become masters of hydraulics by necessity, as their whole country lies twelve feet below the level of the sea. They drained the Haarlem Lake, twelve miles long, seven miles wide, and fourteen feet deep, and covered it with thriving farms and villages, and were so pleased with the speculation that they have now undertaken to drain off the Zuyder Zee, which embraces an area of 759 square miles, and by which they propose to add six per cent. of fertile land to the total area of the country. It is a dull waste of half-navigable waters with low, marshy borders. They are first to construct an immense dike 164 feet wide at the bottom of the sea, and rising to a height of twenty-six feet above it, making a total length of wall, near the narrow opening of the sea, twenty-five statute miles. The inclosed area will be divided into squares, and pumped out at an expense of $48,000,000, or about $100 an acre. Our Yankees, who are being drowned by the score in the overflow of their ponds, might learn something about dams from these Dutchmen.

The president next attacks Asia, and gives us a great deal of valuable information of the results of geographical inquiry in various portions of its immense area, of which the following has a very human interest:

> "Mr. Bond, of the Indian Trigonometrical Survey, discovered two of the wild dwarfish race who live in the hill-jungles of the Western Gâlitz, to the southwest of the Palini Hills, a race which, though often heard of, no trace of had previously been found by the survey. A man and a woman were discovered The man was four feet six inches high, and. 26¼ inches about the chest. He had a round head with coarse, black, woolly hair and dark-brown skin, a forehead low and slightly retreating, the lower part of the face projecting like that of a monkey, with thick lips, protruding about an inch beyond his nose; a comparatively long body for his size, with short, bandy legs, and arms extending almost to his knees. The hands and fingers were so contracted that they could not be made to stretch out straight and flat. The palms and fingers were covered with a thick skin, particularly the tips of the fingers, the nails being small and imperfect, and the feet broad and thick-skinned all over. He had a grayish-white, scanty, coarse mustache like bristles, but no beard. The woman, who was about of the same size, was of yellow tint, with long, black, straight hair, and features well formed as contrasted with those of the man, there being no difference between her appearance and that of the common women of that part of the country. She had an agreeable expression, was well developed and modest. Their simple dress was a loose cloth, and, though they ate flesh, they lived chiefly on roots and honey. They have no fixed dwelling-places, but sleep between rocks, or in caves, near which they happen to be at night, when they light a fire and cook what they have collected during the day, maintaining the fire during the night for warmth, and to keep off wild animals. Their religion, such as they have, is the worship of certain local divinities of the forest. This is a new pygmy race, resembling the African Obongos of Du Chaillu, the Akkas of Schweinfurth, and the Dokos of Dr. Krapf, in their size, appearance and habits."

Africa is, however, now the great point of assault by geographical explorers, and there come the most wonderful revelations regarding the fertility and beauty of various of its extensive regions, with curious descriptions of its government and peoples. Dr. Nachtigal, describing Wadai, in Northeast Africa—

> "Fixes the population of the country at about two and a half millions, and says that the surface elevation of the land is from west to east, with an elevation of from 1,000 to 1,500 feet above the sea-level. Numerous small streams flow from the eastern heights, falling into the two principal rivers, the Kafa and Peaka. The country is divided

into seven provinces; the religion is Mohammedan, and the king, whose power is arbitrary, is looked upon as a sort of divinity. The king's harem consists of about 500 wives, and all his sons, except the heir to the throne, are blinded with hot irons, a duty performed by the king of the smiths, who is also the surgeon of the harem. The people are skillful workers in iron, but given to the drinking of an intoxicating beer, a practice which great efforts are made to repress. Spies are extensively employed for that purpose, and any man upon whose premises the forbidden liquor is found is punished by having his wife's head shaved. The king has an army of 40,000 infantry and 6,000 cavalry, and the country is heavily taxed for the support of the king and his expensive government."

Judge Daly quietly compares our own "best Government on the face of the earth" with one of these African governments, and finds the comparison "not complimentary to our intelligence." Here is the passage:

"The Egyptian Geographical Society, under the presidency of Dr. G. Schweinfurth, the distinguished African explorer, was established this year at Cairo, through the liberality of the Khedive, consisting of 300 members, with an annual income of $7,000. A substantial portion of this income is granted by the Government in view of the advantages to the nation of the labors of the Geographical Society, as is the case with several of the leading Geographical Societies of Europe. But it would be hard to convince our Government of the utility of aiding, by pecuniary means, our Society, the only one in this country, when it would not even incur the expense of sending a commissioner to the late great Geographical Congress at Paris, and to our shame we were the only civilized nation that was unrepresented in the exposition. It is not complimentary to our intelligence and our cosmopolitan relations to the world, of which we form so important a part, that we have a Government that takes no interest in the advance of civilization, and of the trade, commerce, and industry of the world at large, through geographical exploration and discovery, the means by which it has been chiefly advanced, from the dawn of civilization to the present time. It was not the fault of this Society that our country was not represented in the exposition, for earnest efforts were made by us as well as by the French minister, but were met by the reply that the Congress in Paris was the affair of a private society, which was not the view taken by the other civilized nations, who made liberal grants of money for the success of an undertaking in which the whole world was interested. With our limited means, all that we could do was to send a delegation, as nothing could be received for exhibition except under the charge of a commissioner of the government of the country from which it was sent. If the gentlemen charged with the administration of our Government read the frequent expressions of surprise that I have read in the various accounts written of the exposition, at the absence of any representation from the United States, they would not, I think, be very much impressed with the wisdom and policy of the exceptional position in which they placed our country and people. This was not a case in which we could afford to be indifferent, as we do not constitute the whole world."

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### *THE "ACADEMY" FOR AMERICANS.*

We had occasion some time ago to refer to the unscrupulous critical spirit which animates a London weekly called the *Academy*, a periodical established and conducted on the principle of bullying itself into notice by copying and exaggerating the most arbitrary features of British journalism. A special effort has been made to push the circulation of the *Academy* in this country, which makes it proper to point out the policy it has adopted toward American as well as English authors. A little American book on botany was republished in London, and attacked by the *Academy* in the most vicious way. The criticism was a string of the grossest misrepresentations, by which the whole character of the book was falsified and libeled. Its author happened to be in London at the time, and wrote a letter to the editor of the *Academy*, exposing the character of its criticism. The editor refused to print it, and the author was compelled to seek another channel to get the true state of the case before the public. The letter declined by the *Academy* was printed by the *Examiner*.

A similar thing has just been done again. Max Müller was allowed to use the *Academy* columns to abuse and misrepresent Prof. Whitney, of Yale College, in matters of philology. The American linguist replied to these assaults in a letter to the *Academy*, which again its editor refused to print, and it found publicity, as before, through the hospitable pages of the *Examiner*. And this difference of fairness between the two journals goes along with other differences which will be of interest to American readers; for, while the *Academy* is characterized by the amount of its pedantic rubbish and scholarly trumpery, suited to the learned drones of Oxford and Cambridge, the *Examiner* addresses itself more to the living questions of the day, and discusses subjects of universal interest, with an ability and independence that may commend it to American readers desiring an English weekly.

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# LITERARY NOTICES.

The Unseen World, and other Essays. By John Fiske, M. A. LL. B. Pp. 349. Price $2. J. R. Osgood & Co.

To say that this volume is by the author of the "Outlines of Cosmic Philosophy" will be at once to commend it to a large circle of readers; but as a series of interesting papers on a wide variety of topics, scientific, philosophic, artistic, historical, and critical, it will be commended to many who have not been attracted to the earlier and more solid publication. Most of the articles of the volume will be remembered as they appeared in the periodicals; admirable in style, bold in thought, and rich in scholarly erudition. Mr. Fiske has views of his own which he works out with freedom, and often with great beauty and force of statement.

The volume takes its name from the first two essays, which lately appeared in the *Atlantic Monthly*, and were read with interest by many thoughtful people. They start from the speculations of a recent book entitled "The Unseen Universe," which broke into a somewhat new field of ingenious scientific conjecture, and was read with an eager but rather perplexed curiosity by those who are fond of transcendental inquiries. This work has been already noticed in the Monthly, and is chiefly important as an effort by thoroughly disciplined scientific men to arrive at the conception of immortality and a realm of future spiritual life from the scientific point of view. Mr. Fiske is in sympathy with this aspiration, but deals with the problem by his own methods, and perhaps in an abler way than the authors who opened the discussion. We cannot here reproduce his views, which are only to be understood by a careful perusal of the essays in which they are presented.

But, while cordially recommending this volume as a whole, we must except the review of Draper's "History of the Conflict between Religion and Science," which we think somewhat unworthy the author. Mr. Fiske adopts a deprecatory tone in speaking of Draper's books, which is construed by the newspapers into contempt—which jumps with public prejudice, and is quite to be expected from certain quarters; but for which he gives us no satisfactory reasons.

He charges Dr. Draper with superficiality and mental idiosyncrasy, in not understanding Rome; in not appreciating Greece; in hostility to the Catholic Church; in overrating semi-barbarous civilizations, "and above all an undiscriminating admiration for everything, great or small, that has ever worn the garb of Islam, or been associated with the career of the Saracens." But, after indulging in a little sarcasm at Dr. Draper's admiration of the "turbaned sage," Mr. Fiske finds himself compelled to say:

> "Speaking briefly with regard to this matter, we may freely admit that the work done by the Arabs, in scientific inquiry as well as in the making of events, was very considerable. It was a work, too, the value of which is not commonly appreciated in the accounts of European history written for the general reader, and we have no disposition to find fault with Dr. Draper for describing it with enthusiasm. The philosophers of Bagdad and Cordova did excellent service in keeping alive the traditions of Greek physical inquiry at a time when Christian thinkers were too exclusively occupied with transcendental speculations in theology and logic. In some departments, as in chemistry and astronomy, they made original discoveries of considerable value; and if we turn from abstract knowledge to the

arts of life, it cannot be denied that the mediæval Mussulmans had reached a higher plane of material comfort than their Christian contemporaries. In short, the work of all kinds done by these people would furnish the judicious advocate of the claims of the Semitic race with materials for a pleasing and instructive picture."

Very well; these are facts of some importance, but who had brought them out for public appreciation before Dr. Draper published his "History of the Intellectual Development of Europe?" And, although Mr. Fiske may differ from him in regard to the historical import of Arabian science, we fail to see any occasion for the indulgence of sneering and disparagement.

And now in regard to the "Conflict." The theologians of all ilks, who have taken up Dr. Draper's recent book, are agreed that it is a piece of futility because there is really no such conflict as that of which he pretends to have given the history. Messrs. Brownson, Hill, Washburn, Deems, and Co., are vehement in asserting the groundlessness and absurdity of Dr. Draper's assumption; and now, as if he had been sitting under the droppings of the Hippodrome, Mr. Fiske cordially acquiesces in the ardent views of these gentlemen. He says of Dr. Draper: "When he enlarges on the trite story of Galileo and alludes to the more modern quarrel between the Church and geologists, and does this in the belief that he is thereby illustrating an antagonism between Religion and Science, it is obvious that he identifies the cause of the anti-geologists and the persecutors of Galileo with the cause of Religion. The word 'religion' is to him a symbol which stands for unenlightened bigotry or narrow-minded unwillingness to look facts in the face. . . . It is, nevertheless, a very superficial conception, and no book which is vitiated by it can have much philosophic value. . . . Since, then, the scientific innovator does not, either voluntarily or involuntarily, attack religion, it follows that there can be no such 'conflict' as that of which Dr. Draper has undertaken to write the history. The real contest is between one phase of science and another." This will hardly do. Mr. Fiske says that no book vitiated by this superficial conception can have much philosophic value. But, in the "First Principles" of Herbert Spencer, on page 11, we read:

"Of all antagonisms of belief, the oldest, the widest, the most profound, and the most important, is that between religion and science. It commenced when the recognition of the simplest uniformities in surrounding things set a limit to the previous universal fetichism. It shows itself everywhere throughout the domain of human knowledge, affecting men's interpretations alike of the simplest mechanical accidents and of the most complicated events in the histories of nations. It has its roots deep down in the diverse habits of thought of different orders of minds. And the conflicting conceptions of Nature and life which these diverse habits of thought severally generate, influence for good or ill the tone of feeling and the daily conduct. An unceasing battle of opinion like this, which has been carried on throughout all ages, under the banners of religion and science," etc.

Mr. Spencer, of course, holds to the possibility of an ultimate reconciliation between Religion and Science, but he does not commit the folly of denying their past and present antagonism. Dr. Draper has made no attempt to deal with the philosophy of the subject, and he is not to be judged by that standard. Assuming, as Spencer has done, that it is a fact, and a fact of vast significance, he is the first to have given us its history; and, whatever opinion may be entertained regarding the manner of its execution, he had a valid theme, and deals with veritable phenomena. And, had his manner of doing the work been more open to attack, we should probably have heard a good deal less about the baselessness of the antagonism which he has described.

The point of contention is as to what constitutes religion. Dr. Draper was justified in taking the term in its current significance as comprehending the general doctrines and policy of religious organizations. That sects differ, and eat each other up in their denials of dogmas, was nothing to him. And, though they should all agree at last as to what religion is, and discredit the total affirmations of past theology, the historical aspects of the case will remain the same. He was not called upon to settle sectarian disputes, or to find out that denomination which possesses the true faith. Mr. Fiske complains of him for not defining this element of his thesis, and he proceeds to do it himself, as follows: "All animals seek for fulness of life; but in civilized man this craving has acquired a moral significance, and has become a spiritual aspiration; and this emotional tendency, more or less strong in the human race, we call religious feeling or religion." Admirable! but how far accepted? We hope that the agreement of Messrs. Brownson, Hill, Washburn, Deems, Fiske, and Co., in denouncing the groundlessness of the "conflict," will not be construed as implying any agreement among the parties as to what religion is. If these gentlemen will get together and settle the point, an important step will be gained; and THE POPULAR SCIENCE MONTHLY will gladly pay the expenses of a convention of reasonable length for such a purpose, but we stipulate not to foot the bills until they reach an agreement.

A SHORT HISTORY OF NATURAL SCIENCE AND OF THE PROGRESS OF DISCOVERY FROM THE TIME OF THE GREEKS TO THE PRESENT DAY. For the Use of Schools and Young Persons. With Illustrations. Pp. 467. D. Appleton & Co. Price, $2.

WE called attention recently to the influence of the Centennial in stimulating the study of political history, and expressed the hope that the gathering together of the products of art, science, and industry, of all nations, at the Great Exhibition in Philadelphia, would have the effect of promoting the historical study of this class of subjects in American schools. It was pointed out that this line of literature has been greatly neglected, and is so backward that students desiring to attend to it would be much perplexed to find suitable text-books for the purpose. An important and very successful step has, however, been taken to supply this deficiency. The work now published under the above title, considering that it is the first attempt to treat the history of science in a brief and popular way for educational purposes, is of very superior merit. We took it up with doubt, we read it with a growing interest, and cordially recommend it both for general reading and as a school-book. The authoress has made no scientific discoveries; and we question if there are many who have done so who could make so judicious a compend of general scientific history as she has done. But, if she has not made a name as an explorer, she has been a careful student of science, and, having been for many years secretary to the late Sir Charles Lyell, and brought into contact with many of the leading scientific men of the day, she had peculiar opportunities of qualifying herself for the task of writing a popular scientific history. Her style is clear and direct, and her power of explanation we think something quite unusual, while the proportions in which the subjects are treated evince good artistic judgment in the work of book-making. Illustrations are introduced with discretion, to help the text, and brief biographical notices are interspersed which give interest to the course of the narrative, and the exposition of scientific work. The book is, moreover, essentially accurate and trustworthy; and executed with far more faithfulness than is usual in compilations. Miss Buckley's volume ought to be unhesitatingly and extensively adopted in our schools, and kept there until superseded by a better, which we suspect will not be very soon. We do not recommend it to be memorized, or made a matter of formal recitation, so much as for a reading-book to be gone over by suitable classes, with such questions and suggestions as an intelligent teacher can impart. So used, its influence in schools cannot be otherwise than valuable.

DISEASES OF MODERN LIFE. By B. W. RICHARDSON, M. D., F. R. S. Pp. 520. New York: D. Appleton & Co. Price, $2.

WE have already given some excerpts from advance-sheets of this book, which is just issued. Dr. Richardson was led to the treatment of the subject by having first given special attention to the diseases of overworked men. He printed some essays on this topic, and followed them by others on diseases induced by various occupations and by indulgence in the use of alcohol and tobacco. These articles, having undergone revision and considerable extension, make up the present volume. The author carefully abstains from infringing upon the proper art of curing disease which belongs to the medical practitioner, and confines himself mainly to the symptoms and causes of modern maladies, and to hints toward their prevention. While the book will not be without value to physicians, it is carefully adapted to the wants and capacity of general readers. We have simply to say that this volume is, in a high degree, both interesting and useful. It presents in a pleasant form, and with pointed applications, the sort of information that should be most widely distributed, and abounds in facts and suggestions of importance that cannot be readily obtained elsewhere.

Floral Decorations for the Dwelling-House. A Practical Guide to the Home Arrangement of Plants and Flowers. By Annie Hassard. American edition, revised. With many Illustrations. Pp. 166. New York: Macmillan & Co. Price, $1.50.

This little book, written by a person who evidently understands fully the art of floral decoration, will be found helpfully suggestive to all those who wish to make flowers accessory to the attractiveness of their homes.

The author aims, by both illustration and statement, to render the principles underlying her art so plain that any woman may tastefully and successfully decorate her table, adorn her drawing-room, and in some sense, by the use of plants around her windows and balconies, bring to the interior of home not only the beauty but the simple delights of the external garden. The whole subject of table-decoration, including forms of stands and vases, the arrangement of fruit and flowers, the adjustment of these to the light, materials and means for keeping flowers fresh, as well as window-gardening, hanging baskets, grouping of plants, wreaths, crosses, and even button-hole bouquets, find very instructive treatment in this little volume. It is shown how the simplest available materials—ferns, grasses, autumn leaves—no less than the richest products of the florist's art, may serve, in the hands of the skillful manipulator, to produce most graceful effects.

The chromatic principles of grouping are indicated in the following extract:

> "In producing harmonious contrasts of colors, it should be remembered that there are only three primary colors—red, blue, and yellow. From these arise what are called the binary or secondary colors, namely, orange, composed of yellow and red; purple, composed of blue and red; and green, composed of yellow and blue. These form contrasting colors to the primary three with which they are in harmonious opposition, as the orange with blue, purple with yellow, and green with red. From the combination with these secondary colors arise three tertiary colors—olive, from purple and green; citron, from green and orange; and russet, from orange and purple. These tertiary colors harmonize with the primaries, as they stand in the relation of neutral tints to them, but are in harmonious opposition to the secondaries from which they are combined. Red, blue, and yellow, harmonize with each other, and they may be placed in juxtaposition, but purple should not be near red or blue, as it is composed of these two colors, the rule being that no primary color should be brought into contact with a secondary of which itself is a component part; nor any secondary color brought into contact with a tertiary color of which it is a component part."

Memoir and Correspondence of Caroline Herschel. By Mrs. John Herschel. With Portraits. Pp. 355. New York: D. Appleton & Co. Price, $1.75.

This is one of the most fresh and charming volumes that has come from the press in many a day. It is of such unique and special attraction that we have drawn upon it for the materials of two articles in the Monthly, which cannot fail to incite the reader to desire the perusal of the whole book. And it will amply repay the most careful reading. Aside from the interest at every step in the life of the remarkable woman who tells her own story in such a vivid and racy way, this biography will have permanent value as connected with the rise of modern sidereal astronomy, and as throwing light upon the characteristics of an illustrious scientific family. Telescopes, new planets, comets, double stars, and nebulæ, are always attractive things to read about, but what engages us most intently with these pages is that they overflow with human nature from beginning to end.

Analytical Processes; or, The Primary Principle of Philosophy. By William I. Gill, A. M. Pp. 483. New York: The Authors' Publishing Company. Price, $2.

The author of this book made his mark as an acute and independent thinker by the publication, a year or two since, of a volume called "Evolution and Progress." The present volume is the first of a series, each complete in itself, in which a fresh attempt will be made to construct a philosophy. No intimation is given as to what will be its character, the present book being occupied entirely with the foundation, and with only one element of that—the primary principle of all reasoning. This principle the author finds in the law of noncontradiction, which simply says to system-makers, "Be consistent, or do not contradict yourselves." Obvious as this principle is, we are told that in all ages it has been accepted or rejected alternately according to the exigencies of philosophical speculation, having been nullified by theologians and philosophers from Augustine to Kant. It therefore needs reëlucidation, to which Mr. Gill has devoted his volume. The book gives abundant scope for the exercise of philosophical genius, in which its author is not wanting. Our most eminent metaphysicians, as Drs. McCosh and Anderson, recognize his strong claims as a thinker, and we have no doubt his volume will attract the attention of serious students, and prove a valuable addition to American philosophical literature.

Military Map of the Indian Territory. Compiled by First-Lieutenant E. H. Ruffner, of the Engineers.

This valuable map, the preparation of which has occupied Lieutenant Ruffner and Mr. Ado Hunnius, draughtsman and engraver, for some three years, is based on Government and railroad surveys, previously-published maps, military surveys and reconnoissances, etc. The scale is made large enough for marching-purposes, and the topographical details are such as are needed in directing military movements. The task of compiling such a map as this of the Indian Territory is one that involves an enormous amount of labor, and it appears to have been performed with conscientious fidelity by Lieutenant Ruffner. The draughtsman's work is also deserving of great credit. The map is on the scale of 1 : 500,000.

We have received the initial number of *The Home Scientist*, published at Wadsworth, Ohio. The *Home Scientist* is a monthly, eight-page journal, in quarto, devoted to the diffusion of popular scientific knowledge. This first number, both in its original and in its selected matter, shows evidence of competent editorship. We wish it success. J. A. Clark, publisher. Terms, $1 per annum.

The Polytechnic Review.—We have received from the publishers the first number of a monthly periodical bearing the above title. In form it is a large quarto of twelve pages, tastefully printed on fine paper. The *Review* is designed to chronicle and illustrate the progress of science as applied to the useful arts, such as engineering in all its branches—civil, mechanical, naval, military, and sanitary; gas and water supply, and sewerage; chemical technology, with particular reference to mining, metallurgy, and manufacturing chemical industries; manufactures in general, and the mechanic arts. That the *Polytechnic Review* will be conducted with energy and ability, the names of the editors, William H. Wall, Ph. D., and Robert Grimshaw, Ph. D., are a sufficient guarantee. Philadelphia: Published by the editors, 119 South Fourth Street. $3 per annum.

### PUBLICATIONS RECEIVED.

Geological Survey of Alabama. Report of Progress for 1875. By Eugene A. Smith, Ph. D. Montgomery, Alabama, 1876. Pp. 212.

Memoirs of the Peabody Academy of Science, vol. i., No. iv. Fresh-Water Shell Mounds of the St. John's River, Florida. By Jeffries Wyman, Salem, Massachusetts. Pp. 87.

Statistics of Births, Marriages, and Deaths, in the City of Philadelphia for the Year 1874. Compiled by William H. Ford, M. D. Philadelphia, 1875. Pp. 133.

Experiments with the Alleged New Force. By George M. Beard, A. M., M. D., New York, 1876. Pp. 28.

Report of the Health-Officer of the City of Oakland, California, 1875. By George E. Sherman, M. D. Oakland, 1876. Pp. 32.

Reports of the Trustees and Superintendent of the Butler Hospital for the Insane, Providence, 1876. Pp. 37.

Immobility or Closure of the Jaw, with Report of Cases. By W. F. Westmoreland, M. D. Atlanta, Georgia, 1875. Pp. 10.

The Public-School Question as understood by a Catholic-American Citizen and by a Liberal American Citizen. By Bishop McQuaid and Francis E. Abbott. Boston, 1876. Pp. 100.

Historical Sketch of the Columbus Public Schools. Columbus, Ohio. Pp. 31.

An Exposition and Defense of Homœopathy. By George Pyborn, M. D. Georgetown, Colorado, 1876. Pp. 36.

Legal Chemistry, A Guide to the Detection of Poisons, Examination of Stains, etc., as applied to Chemical Jurisprudence. By A. Naguet. Translated by J. P. Battershall, Nat. Sc. D., with a Preface by C. F. Chandler, Ph. D., M. D., LL. D. New York: D. Van Nostrand, 1876. Pp. 178. Price, $2.

Life Histories of the Birds of Eastern Pennsylvania. By Thomas G. Gentry. In Two Volumes. Vol. i. Philadelphia, 1876. Pp. 399.

Prehistoric Man. By Daniel Wilson, LL. D., F. R. S. E. In Two Volumes. London: Macmillan & Co., 1826. Pp. 391 and 401. Price, $12.

Report of the Chief Signal-Officer to the Secretary of War for the Year 1875. By Albert J. Meyer. Pp. 475. With numerous Maps.

Exercises in Electrical and Magnetic Measurement. By R. E. Day, M. A. London: Longmans, Green & Co., 1876. Pp. 120.

Daily Bulletin of Weather Reports, Signal Service of the United States Army for April, 1875. Pp. 185.

Man a Spirit only. By R. L. Farnsworth. Pp. 48. St. Paul: *Pioneer Press* print.

Claims of Capital. By William Brown. Pp. 36. Montreal: J. Lovell.

Uses of a Topographical Survey of New York State. By J. T. Gardner. Pp. 14. New York: American Geographical Society.

Product of the Action of Potassium on Ethyl Succinate. By I. Remsen. Pp. 10. From *American Journal of Science.*

Hospital and Private Treatment of Ophthalmia Neonatorum. By S. C. Ayres, M. D. Pp. 8. From *Lancet and Observer.*

Climate in its Sanitary Relations to Medicine. By A. S. Baldwin, M. D. Pp. 14. Jacksonville, Fla.: *Semi-Tropical* print.

Report on Working-Women's Protective Union (1876). Pp. 16. New York: W. W. P. Union.

Astronomische Nachrichten. No. 2,062. Kiel: Königliche Sternwarte.

Training-School for Nurses. Pp. 16. Philadelphia: Grant, Faires & Rodgers print.

Principal Characters of the Dinocerata. By O. C. Marsh. Pp. 6. With Plates. From *American Journal of Science.*

Some Remains of an Extinct Species of Wolf. By J. A. Allen. Pp. 5. From *American Journal of Science.*

Doctrine of Force, and its Bearing upon Theism. By G. N. Duzan, M. D. Pp. 39. Indianapolis: J. G. Doughty print.

Memorial to Congress on the Currency, from the New York Board of Trade. Pp. 13.

Report on Chicago Botanical Garden (1875). Pp. 4.

Report of the Georgia Commissioners of Agriculture (1875). Pp. 180. Atlanta: Estill print.

*Polytechnic Review.* Vol. i., No. 1. Monthly, $3 per annum. Philadelphia: W. H. Wahl and Robert Grimshaw, proprietors.

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## MISCELLANY.

**Unhealthiness of New Houses.** — The unhealthiness of new houses is due to the presence of moisture in their walls. This moisture may be held either mechanically, as by capillary attraction in the bricks, mortar, and plaster; or chemically, in the hydrate of lime. Moisture held mechanically is removable by air and warmth; chemically-held moisture is removed gradually by the action of carbonic acid contained in the air. A writer in the *English Mechanic* suggests the use of a dew-point thermometer as a means of determining whether a house is sufficiently free from moisture to be inhabitable. If we take a reading of this in the open air, in the shade, and protected from wind, we have the actual atmospheric conditions. If we now transfer the instrument to a room in the house which has been closed for a few hours and without artificial heating, we find the internal conditions. If the dry thermometer is lowered, we may conclude that the walls are cold, and so absorb heat. If the difference between the wet and dry bulbs is lessened, we know the evaporation conditions are lessened; that is, that the internal atmosphere is overcharged with moisture. The two together will prove that the walls are damp, and that the house is disadvantageous to health.

**New Tanning Process.**—An exhibition was recently given at Havre, France, of Montoison's process of tanning. A variety of skins were experimented on, from the fresh skin of a calf, to the old skins of sheep and goats burnt and hardened by a tropical sun; more time of course was required to unhair the latter than the former. The skins were first soaked in hot water, then they received two coats of a pasty liquid on the inside, and were piled up, inside to inside, to undergo the action of the composition. After the skins had been soaked for a short time, the wool and hair came from them absolutely intact. The manner in which the wool came away from the skin by a touch of the hand created considerable astonishment in the minds of those who witnessed the experiments. In a few seconds the skins were dipped in two special baths to neutralize the unhairing composition, and the afternoon was devoted to tanning experiments, which proved the invention to be a complete success. Experienced tanners, who were present, declared the leather produced to be, to all appearance, fully equal to that produced by the tedious methods in common use.

**The Economy of Vegetarianism.**—A writer in the *Quarterly Journal of Science* makes a trenchant criticism of the arguments usually employed by vegetarians in support of their system of diet. The author considers the question from the economic, the moral, and the hygienic points of view, but we have not space to give more than an epitome of his remarks on the first of these topics. One hundred acres of good land, say the vegetarians, will support a greater amount of human life if planted with wheat, potatoes, or other crops directly consumed by man, than if laid out in pasture or set with vegetables intended for the food of cattle. This is true, but all land is not *good;* in every country there is abundance of land that is unfit for tillage, and which, nevertheless, yields excellent pasture. Under a vegetarian *régime* such lands would cease to supply the food-market. So too the produce of the forest and moor—game—would cease. More serious still, the waters would no longer contribute their share. It might be said that poor lands could still be used for pasture, and the produce of flocks and herds (wool, butter, cheese, milk) utilized. But if the grazer cannot sell the meat, it would be unprofitable to keep animals, unless he could get, for the products above named, prices a hundredfold higher than he gets now. Besides, the use of milk, butter, and cheese, is inconsistent with vegetarian principles. In a strictly vegetarian country, tallow, hides, and hair, could scarcely be procured. Again, the refuse of the fisheries is rising into importance as a manure fully equal to Peruvian guano. But, if fish might no longer be captured, the supply of this fertilizer would be cut off, unless indeed the destruction of animal life for purposes other than food received an exceptional sanction. Even then the cost of the raw material would be greatly enhanced.

**Ancient American Civilization.**—In the "Congress of Americanists," held last July at Nancy, France, a very learned paper was read by Prof. Foucaux, of the Collége de France, in favor of the theory that the ancient civilization of America is the work of Buddhist missionaries. The theory was hotly attacked by several of the distinguished men present, among them by Friedrich von Hellwald. The latter compared the story of Huei-shen to that of the sea-serpent. Dr. Hellwald is of the opinion that this theory received its death-blow at the Congress. Two other theories were also very badly damaged, namely, those of a lost continent of Atlántis and of Phœnician settlements in America. M. Léon de Rosny delivered a masterly address on the Maya hieroglyphics. The *Maya* was the sacred language of the ancient inhabitants of Yucatan, and the monuments of that country bear a number of inscriptions in a hieroglyph which has been only very partially deciphered as yet. M. de Rosny first critically analyzed the attempts at decipherment made by his predecessors, the Abbé Brasseur de Bourbourg and H. de Charencey. The Bishop Diego de Landa first discovered a clew to the meaning of these hieroglyphs; he made out the meaning of seventy-one signs, and the number has been increased to one hundred and thirty-two by De Rosny. The latter has also determined the order in which these signs should be read. As a rule, they run from left to right, but in exceptional cases from right to left. M. Oscar Comettant, of Paris, a musician and composer, attended the Congress expressly for the purpose of reading a deeply interesting paper on "Music in America before its Discovery by Columbus." The author described the Peruvian flute, and, to give the audience an idea of ancient Indian music, had a few simple native Peruvian melodies performed by members of the garrison band. The effect was very pleasing. A comparison of this music with that of China shows that the two are in no respect alike. Here was a new and unexpected argument against the truth of the Huei-shen story. The next meeting of the "Congress of Americanists" will be held in 1877, in the city of Luxembourg.

**Climatology of New Zealand.**—The two large islands of the New Zealand group, North and South Island, are both very mountainous. In the North Island the mountains occupy about one-tenth of the surface, and in the South nearly four-fifths. The rivers are very numerous, and of large size in proportion to the area of the country; but few of them, however, are navigable. The greatest height of the main range in North Island is 6,000 feet; but in the South Island there are peaks from 10,000 to 14,000 feet in height. The changes of weather and temperature in New Zealand are very sudden; calms and gales, rain and sunshine, heat and cold, alternate so frequently and suddenly as to defy previous calculation, so that there is no uniformly dry or wet season in the year. But, though these changes are sudden and frequent, they are confined within very narrow limits, the extremes of daily temperature varying throughout the year by an average of 20° only, while in Europe, at Rome, and other places of corresponding latitude with New Zealand, the same variation is 30° or more. In respect to temperature, New Zealand may be compared either with England or Italy; but London is 7° colder than the North, and 4° colder than the South Island, and is less moist. Strong winds are prevalent, and particularly in the straits. Rain falls frequently, but seldom in such excessive quantity, or for such long periods, as in Australia. The rainfall, in 1871, was 54½ inches; that of New York City in 1873 was 42½.

**Science-Teaching for the Young.**—The master of a school for young boys gives an account in *Nature* of his method of teaching his young pupils science. For the purposes of scientific instruction, the pupils are divided into three classes, the lowest of which contains about twenty boys, whose average age is nine years. Class II. is composed of ten boys, of an average age of twelve years, while the first class contains twelve boys, of an average age of twelve and a half years. The time weekly devoted to science-instruction is, for Class III., two lessons in botany of three-quarters of an hour each, and one hour's lesson in physical geography. The pupils are taught to distinguish the parts of a flower, and, by the aid of a chart, to discover the order to which any plant belongs. The second class gives two and a half hours per week to botany. The standard of knowledge aimed at is such as is contained in Prof. Oliver's books, and the boys are expected to be able to find out any given plant in Bentham's "British Flora." The boys in the first class study chemistry, and spend one afternoon of an hour and a half at practical work in the laboratory. Another afternoon is employed in listening to a lecture founded upon a chapter in a text-book of chemistry. The boys, after the lecture, study up its subject-matter in the text-book, so as to be able to answer questions on it at the beginning of the next lesson. The standard aimed at is the power to discover a simple acid and base, and an acquaintance with the text-book.

"These sciences," continues the author, "were chosen less as subjects of study than as instruments of training in order to cultivate the powers of observation, and to encourage a habit of inductive reasoning. If the teaching of science in its early stages is thus regarded more as a means than as an end, there is no child, who has begun to learn anything at all, who may not be taught some branch of it with advantage." The attempt was at first made to teach the children science without making them learn anything by heart. The result was, that they did not know what to do with the facts they had collected, and lost them as fast as they picked them up. "But, since the botany boys have been set to learn the chart by heart, and since the chemistry boys have been using a text-book, the progress made has been far more satisfactory. A young child's reasoning powers are so feeble that he needs to be constantly guided in the use of them, and, before being set to observe, he requires to be furnished with a *cadre* in which to arrange his battalions of facts."

**Fishing for Glass-Sponges.**—The mode of fishing for the *Euplectella*, or "Venus's Flower-basket," on the coast of Zebu, one of the Philippines, is described as follows in the journal of a member of the Challenger Expedition: "The natives use an ingeniously-contrived instrument in taking the sponges. Two long strips of bamboo meet at an angle of 45°, and are fixed in that position by an elaborate system of stays of bamboo, which are attached to a piece of wood running back from the angle, between the two arms or wings of the machine. The piece of wood is weighted with stones, and a line is attached to it, so that the machine is pulled along on the bottom, with the angle in advance, and the two wings sloping backward. The outer edge of each of the bamboo rods is armed with between thirty and forty large fish-hooks, with their barbs set forward. The *regederas*, as the Spaniards call the euplectellas, are found at a depth of about a hundred fathoms. The Indian lets down the machine with a strong fine line of Manila hemp, and pulls it slowly over the ground. Every now and then he feels a slight tug, and at the end of an hour or so he pulls it in, with usually from five to ten *regederas* on the hooks. Euplectella has a very different appearance, under these circumstances, from the cones of glassy network so well known under that name. Its silver beard is clogged with the dark-gray mud in which it lives buried to about one-third of its height, and the network of the remainder of the tube is covered with a pall of yellowish sarcode.

**Congress of German Anthropologists.**—The Congress of Anthropologists held its sessions for 1875 in Munich, in the early part of August. The president, Prof. Virchow, reviewed the history of the German Anthropological Society since its origin, sixteen years ago. Prof. Zittel called the attention of the delegates to the collection of prehistoric relics on exhibition in one of the halls of the Odeon. The collection represented the ancient Kelto-Germanic period of Bavarian history, and was the result of the joint efforts of various historical societies, aided by the Government and by private collectors. "Of Tertiary man," said Prof. Zittel, "no trace is found in Bavaria, any more than in the rest of Germany, nor have we any human memorials from the period of the preglacial Diluvium. Even the Cavern and the Stone age yield but few human remains. Burying-places furnish both dolichocephalous and brachycephalous crania—the latter belonging to Southern Bavaria, the former to the Allemans and Franks. We must not deny to the Bavarian of to-day a Germanic origin on account of his brachycephaly, for even the Frisians are brachycephalic also. In manners and customs Bavaria is as German as any other portion of Germany, and it is not to be dropped out of the German organism. Its post is that of guardian of the southern marches."

**The Weddas of Ceylon.**—A paper by Mr. B. F. Hartshorne, read at the British Association, gives some interesting particulars of the social condition and habits of the Weddas of Ceylon. The Weddas depend for their subsistence on bows and arrows, and pass their lives in the vast forests of the country without any habitation, and without even the rudest attempt at cultivating the soil. No flint or stone implements are to be found among them, and they produce a flame by rubbing two sticks together. Their intellectual capacity is so small, that they are unable to count or to discriminate colors. They are almost destitute of the religious sentiment, as well as of an appreciation of personal cleanliness, for they habitually eschew ablutions. They abhor theft and lying. But, perhaps the most remarkable trait in the character of the Weddas is the apparent absence of a faculty which is held to be peculiar to the human race—that of laughter. It is stated that they regard the expression of mirth by others with surprise and disgust, and that no Wedda has ever been known to laugh.

**Lettuce as Food for Silkworms.**—A writer in *Das Ausland* states that, in the summer of 1873, a few silkworms, belonging to his children, were fed with lettuce for some time after being hatched, mulberry-leaves not being obtainable. The caterpillars ate the lettuce ravenously, but, when they were about half-grown, a supply of mulberry-leaves was procured, and this constituted their food for the rest of the season. The moths in due time spun their cocoons as usual, and the next spring the author himself determined to feed the silkworms only on lettuce. The young brood devoured the lettuce in great quantities, care being taken to leave no moisture on the surface of the leaves. The insects grew and went through their metamorphoses in the usual manner; a few only died, and they from carelessness in not wiping the leaves dry. The cocoons were of good quality, and the author intended to exhibit some of them at the Royal Agricultural Hall in Stuttgart. Time alone can determine whether silkworms will degenerate on being fed on lettuce. However this may be, the subject is one that is worthy of investigation.

**Dredging for Amber.**—According to an official report from Memel, Germany, an establishment has been organized for obtaining amber by dredging in the Kurische Haff, near the village of Schwarzorts, situated about twelve miles south of Memel. It has been known for many years that amber existed in the soil of this place, from the fact that the dredger employed by the Government for clearing away the shallow spots near Schwarzorts, which impeded navigation, brought up pieces of amber, which were duly appropriated by the workmen, and at the time no particular attention was paid to the matter. Some time afterward, however, some speculators associated, and made an offer to the Government not only to do the dredging wherever required at their own expense, but to pay a daily rent, provided the amber which they might find should become their property. This proposal was accepted, and the rent fixed at 15 thalers, and later at 25 thalers, for each working day. The dredging was begun with four machines worked by men, and one worked by horses. Judging from the extended business transactions in this matter, its results must have been extremely profitable. At present, the work is carried on with eighteen steam-dredges and two tug-boats, the whole managed by about 1,000 laborers.

**Temperature of Germination.**—It is generally supposed that the seeds of plants do not germinate at a temperature lower than 4° or 5° Cent. (40° Fahr.), but certain experiments made by Uloth, and published in the German botanical magazine, *Flora*, would seem to show that this opinion is erroneous. In Dr. Uloth's experiments the seeds of *Acer platanoides* and of *Triticum* germinated at a temperature not exceeding zero C. (32° Fahr.). In the winters of 1871–'72 and 1872–'73, he made the following experiments: He took two boxes and in each had a certain depth of water frozen into a block of ice. In these blocks he made furrows four millimetres deep, in which he sowed seeds of various plants, which were the same for the two boxes. He now covered the boxes with a plate of ice, and stored them away in two separate ice-houses. He then partly filled two boxes with soil, in which he sowed the same kinds of seeds. These boxes he also covered with plates of ice, and stored them in the same ice-houses with the others. Care was taken to have a good thickness of ice (over four feet) surrounding the boxes on every side, so as to provide against any elevation of the temperature. The boxes were placed in the ice-houses in January, 1872, at a temperature of —8° C., and they were taken out on May 15th. In 1873, they were placed in the ice-houses in February, the temperature being —5° C., examined on March 25th, and removed on May 15th. The kinds of seed sown were twenty-five in number. On March 25th, four had germinated, viz., *Lepidium ruderale*, *L. sativum*, *Sinapis alba* and *Brassica napus*, all Cruciferæ. On May 15th, besides the foregoing, the following seeds had germinated: *Arabis alpina*, *Æthionema saxatile*, *Brassica nigra*, *Petroselinum sativum*, *Cannabis sativa*, *Ervum lens*, *Pisum sativum*, *Avena sativa*, *Secale cereale*, *Hordeum vulgare*, *Triticum vulgare*.

Hence it appears that the seed of Cruciferæ and of Gramineæ freely germinate at the temperature of zero C. Of the seeds named above, about an equal number germinated in ice and in earth. The radicles had penetrated the blocks of ice. Those seeds which had not germinated lay rotten on the surface of the ice or of the soil.

**Transformation of Species.**—An instance of transformation of species is recorded as follows in the *Zeitschrift für Wissenschaftliche Zoologie*. There are some salt-marshes near Odessa, which in 1871 contained numbers of *Artemia salina*, a minute crustacean, also known as the brine-worm. At that time, owing to the rupture of a dike, the quantity of salt in the pond was very small, the water marking 8° in the Baumé areometer. The dikes were repaired, and concentration then proceeded rapidly until, in September, 1875, the water marked 25°. As the salt was increased the *Artemia salina* was modified from generation to generation, so that, by the end of 1874, several individuals had no caudal lobes (*see* figure of *A. salina* in No. 20 of the MONTHLY, December, 1873), and they presented all the specific characters of *Artemia Mulhauseni*. The changes observed from year to year are minutely described. They appeared especially in the caudal part, and were accompanied by diminution of size. These observations were confirmed by experiments made on *Artemia* kept in water of various degrees of softness. In the inverse experiment from a greater to a less softness, *A. Mulhauseni* returned to the form of *A. salina*. As the saltness increased or decreased, there was an increase of diminution of the surfaces of the bronchiæ. The writer of the article further gives reasons for thinking that the genus *Artemia* is only a degraded form of *Bronchipus*, degraded through the influence of the medium.

**Clothing the Young.** — "Hygiene of Dress" is the subject of a series of articles in the *Sanitary Record*. The author's remarks concerning the proper clothing of infants and children are judicious. "Warmth," he says, "is the first requisite for infants, who are very susceptible to cold. The clothing of the infant should be both light and warm. Its purpose is to protect the infant from chills, or rather to prevent too great a loss of heat. It should be ample enough to prevent any pressure on the blood-vessels, which would impede the circulation and hinder the free development of the members. It should be especially easy over the chest, in order to insure the free play of the lungs and heart, and should be equally ample around the stomach and the intestines, in order not to interfere with digestion. The sleeves should be wide, in order that the garment may be easily put on, and to favor the circulation of the blood in the arteries and veins of the arms and legs. The robe should be long enough to preserve the infant from cold, but not so long as to be a burden. The head should not be covered. A cap often tends to favor congestions; sometimes, too, it compresses the head, and certain cerebral affections have been, apparently with good reason, referred to this cause alone.

**An Automatic Light-Registering Machine.**—Mr. Crookes has made an ingenious application of his radiometer to meteorological purposes. In our present meteorological records we note variations in heat, rainfall, atmospheric pressure, etc., but light, the most important influence, has been neglected hitherto, for the want of a machine for automatically registering its variations. Mr. Crookes has arranged the arms of his radiometer so that they carry round a small magnet suspended beneath them. The amount of light falling on the pith-balls at the extremities of the radiometer arms determines the rate of rotation. Near the magnet, attached to the rotating arms, is suspended another magnet, which oscillates as the attached magnet presents alternately its north and south poles. This oscillation makes and breaks an electric circuit, which, by a wire of any required length, is connected with a recording Morse machine moved by clockwork. Each revolution of the rotating pith-balls is thus recorded by a punch of the Morse on a strip of paper, and so a register is kept of the amount of light falling at any place.

**A Mountain of Granite.**—The "Stone Mountain" of De Kalb County, Georgia, is described in the *American Journal of Science* by Mr. E. Hillyer. It is a solid, bald mass of granite, from 1,500 to 2,000 feet in height. The northeast side is perpendicular, unbroken, and smooth; the northwest side is inclined so as to be of easy ascent; while the west and southwest are so steep as to be barely accessible. On the inclined surface the rock breaks off in layers, a few inches to several feet thick, which structure may be due to shrinking in cooling, and to atmospheric influences, together with solar heat. The rock is perfectly homogeneous, with no trace of stratification—a pure whitish granite. There is no doubt that below the surface lamination a piece could be quarried out a quarter of a mile in length, if man could command the means. This granite exists over a wide region of country, and is much used for building-purposes.

**Rattlesnakes and their Bites.** — In the course of some notes on the rattlesnake, published in *Forest and Stream*, Dr. J. W. Bailey, of Albany, asserts that this serpent is the most sluggish of the snake family. It never strikes unless in self-defense, excepting just before and after its winter sleep. Of course, the rattlesnake's idea of self defense is rather broad. Thus, if a person step upon it by the purest accident the snake will make no allowance, but strikes the intruder on the spot. To strike, however, it must be in close coil, with its head erect. It is capable of springing only a little more than half its length, unless it be lying on an inclined plane; then, by supporting itself entirely on its tail, it can spring much farther. Hogs attack the rattlesnake with impunity, the effect of the poison being probably neutralized by a thick layer of adipose tissue. Dr. Bailey is able to contradict, from his own experience, the statement that serpents do not move about at night; he has often, when riding by moonlight seen them gliding through the grass. The author says that, when the venom of a serpent has entered the circulation, all remedies are unavailing. He has seen a freshly-killed chicken split open and applied to the wound, with good results. In such cases the flesh of the chicken turns green and putrid where it comes in contact with the virus. The most certain remedy, however, is whiskey or brandy used in large quantities —say a quart—immediately. Intoxication is not exhibited until the poison has been counteracted. Sweet-oil, taken in doses of several ounces, is also effectual. Sportsmen camping in Texas are accustomed, after pitching their tent, to stretch around it a hair lariat. The short hairs irritate the snake's belly as he attempts to cross the lariat, and he retreats.

**Cause of Monstrosities.**—In the course of a discussion of the subject of "monstrosities," in the Detroit Academy of Medicine, Prof. Armor, of the Long Island Medical College, who was present, presented some ingenious views, which may be briefly stated as follows: Monstrosity is commonly referred to "arrest of development" or to "abnormal development." But what is the true cause? Prof. Armor answers: 1. Something deficient or abnormal in the generative matter from which the fœtus is developed. This generative matter he looked upon as *representative;* there is not a tissue, structure, or form, that is not represented in it, so that deviation from the normal type may be impressed at the very instant of conception. The next point was the faithful transmission of *acquired* structural peculiarities, when once fully established. Finally, it was suggested that the discussion of this subject bears directly upon the great question of evolution: the strongest and fittest survive; weak parts of the organism atrophy and die — they cease to be seminally represented. 2. The next cause of monstrosities mentioned was such as operated directly on the *fœtus in utero*. The generative matter may be perfect and fully representative, but certain morbid influences may act directly on the fœtus. Dr. Armor instanced the experiments made in producing malformations by submitting hens' eggs to various mechanical influences during incubation. In conclusion, he held that all causes of malformation would come under one of two heads: They are either *generative* or *mechanical*—sometimes one operating, sometimes the other, sometimes both.

**Habitat of the Crocodile.**—Till recently the two American species of crocodile, described by Cuvier, have been supposed to be confined to South America and the West Indies. In 1870 Prof. Wyman identified a skull from Florida as belonging to Cuvier's species, *Crocodilus acutus*. Mr. William T. Hornaday now describes in the *American Naturalist* two specimens—male and female—of the *Crocodilus acutus* which he captured last year in the vicinity of Biscayne Bay, on the southeast coast of Florida. The male was fourteen feet in length, and his girth at a point midway between fore and hind legs was five feet two inches. His teeth were large and blunt; his head rugose and knotty, with armor-plates very large and rough. On dissection it was found that during life he had sustained serious bodily injuries, probably in battle. Three of his teeth were shattered; the tibia and fibula of the right hind-leg had been broken in the middle and again united, also one of the metatarsal bones of the same limb; the tail had been docked, and two of the vertebræ had grown together solidly.

The female measured ten feet eight inches. Her head was regular in outline, comparatively smooth, with white, regular, and sharp plates, even in surface and contour, and colors very marked. The entire under-surface of both specimens was pale-yellow, shading gradually darker up the sides with fine irregular streaks and spots of black. The general appearance of the female was decidedly yellowish, while the back and tail of the male showed an almost entire absence of yellow, the prevailing color being a leaden, lustreless black. While in Florida the author saw the skulls or other remains of three other crocodiles. He observes that all the specimens were taken in water that is brackish about half the time.

**Effects of Strain on the Magnetism of Soft Iron.**—The following account of experiments made by Sir William Thomson, with a view to ascertain the effects of stress upon the magnetism of soft iron, we take from the *Telegraphic Journal*. Wires of steel and of soft iron, about twenty feet long, were suspended from the roof of the physical laboratory of Glasgow University. An electro-magnetic helix was placed around a few inches of each of the wires, so that the latter could be magnetized when an electric current was passed through the former, the induced current thus produced in a second helix outside the first being indicated by a second galvanometer. With steel wire, the magnetism diminished when weights were attached to the wire, and increased when they were taken off; but with "special" soft-iron wire (wire almost as soft as lead), the magnetism was increased when weights were put on, and diminished when they were taken off. Afterward he discarded the electrical apparatus; and, by suspending a piece of soft wire near the magnetometer, consisting of a needle a small fraction of a grain in weight, with a reflecting mirror attached, the wire was magnetized inductively, simply by the magnetism of the earth, and changes in its magnetism were made by applying weights and strains, the changes being then indicated by the magnetometer.

**The Origin of Astronomy.**—Like that of many other sciences and arts, the origin of astronomy has been ascribed to various nations of antiquity, and it is very doubtful if any one of these can lay exclusive claim to the credit of having been its founder. The succession of day and night and of the seasons, the phases of the moon, and the motions of the heavenly bodies, must have enlisted the attention of man from the earliest times and in every clime. The result would naturally be a more or less perfect system of astronomy. Some nations, no doubt, from one cause or another, cultivated this science with more success than others, and among these the Assyrians, Babylonians, or Chaldeans, are preëminent. The records of their observations were adopted by the Greeks, and through the latter were transmitted to the Romans. Thus our modern astronomy is really traceable back to the plains of Babylonia. The question arises, Of what race were the founders of Chaldean astronomy? This subject is considered by A. H. Sayce, who, in a communication to *Nature*, says that they were not Semites, but a people who are now generally termed Accadians, and who spoke an agglutinative language. "They had come from the mountains of Elam or Susiana, on the east, bringing with them the rudiments of writing and civilization. They found a cognate race already settled in Chaldea, and in conjunction with the latter they built the great cities of Babylonia, whose ruins still attest their power and antiquity. Somewhere between 3000 and 4000 B. C., the Semites entered the country from the east, and gradually contrived to conquer the whole of it. It is probable the conquest was completed about 2000 B. C. At all events Accadian became a dead language some two or three centuries later, but, as the Semitic invaders owed almost all the civilization they possessed to their more polished predecessors, it remained the language of literature, like Latin in the middle ages, down to the last days of the Assyrian Empire."

**Sounds produced by blowing into a Flame.** — Some noteworthy observations have been made by Decharme on the production of sounds by blowing into a flame through a tube. He is of opinion that the air acts rather chemically than mechanically. The sounds, according to him, result from small explosions by the combination of the oxygen of the air with the hydrogen or carbon of the flame, in imperfect combustion. For the sound to occur, the presence of air, or of an inert gas mixed with oxygen, seems necessary. In one of M. Decharme's experiments the white flame from a Bunsen burner, with the lateral apertures closed, gave a very strong sound when blown into with a tube; whereas the blue flame, produced when the apertures are open, gave a very weak one, or none at all. Carbonic acid alone, or nitrogen, or oxygen, or chlorine, blown into a flame of illuminating gas, gave little or no sound; protoxide of nitrogen gave a sound that was weak, but more acute than that obtained from air.

**Exploration of Victoria Cave.**—Dr. Tiddeman read a report on the exploration of the Victoria Cave, Settle, during the year 1874–'75. The report assigns to the preglacial or the glacial age the lower deposits of this cave, which contain early Pleistocene animal remains associated with a human fibula. The animal bones were nearly all mere fragments, though one was perfect; they represent bears, oxen, deer, goats or sheep, elephants, swans, etc. Attention was called in the report to the great distance of time which separated that age from our own. In the cave Roman times were separated from our own day by deposits sometimes less than a foot thick, but nowhere by more than two feet of talus, the chips which time detached from the cliffs above. The Neolithic age, which antiquaries know was a considerable time before the Roman occupation, is represented in some places at a depth of four or five feet beneath the Roman layer, but at others it runs into it. Then come nine feet of talus without a record of any living thing. Judging by the shallowness of the Roman layer, this must represent an enormous interval of time. Next come the bowlders, the inscribed records of the Glacial period. They must represent a long series of climatic changes during which the ice was waxing and waning, advancing and moving back over the mouth of the cave. Then there is a break in the continuity of the deposits, the bowlders lying on the edges of the older beds, which shows that time was given for changes to take place to allow the district to cool down from a warmth suitable to the hippopotamus and become a fitting pasture for the reindeer. It was in that warm period that the man lived and died whose fibula occurs among the bones in the cave.

**Methods of preserving Fresh Meat.**—So numerous are the processes devised in modern times for the preservation of food, that a simple catalogue of them would occupy several pages of this magazine. In so far as the preservation of vegetables and of certain fruits is concerned a very fair measure of success has undoubtedly been achieved; but with flesh-meat the case is different. We propose to describe here a few of the chief methods adopted for preserving meats, following for the most part a writer upon this subject in the *Journal of the Society of Arts*. These methods may all be reduced under the four heads of Desiccation, Refrigeration, Use of Chemical Antiseptics, and Application of Heat. Desiccation or drying has been practised from the earliest times. Charqui, or jerked beef, is an example of fairly successful preservation, but it is immensely inferior to fresh meat. Some years ago the food committee of the London Society of Arts reported favorably upon some specimens of "powdered beef" from Queensland; but the article has been unable to win its way to public favor. The reason of this no doubt is, that animal matter preserved by desiccation loses its flavor and becomes tough and indigestible, the fat becomes rancid, and in damp weather the whole turns mouldy and sour. These difficulties are to some extent obviated by mixing absorbent substances with fatty food, as in "pemmican," where sugar and spice are mixed with dry powdered meat. Meat-biscuit is made on a similar principle. Tellier, of Paris, adopts the following method: He first exhausts the air from a close vessel containing the meat, then fills it with carbonic-acid gas, again exhausts and again fills with the same gas. In this way the air is almost entirely removed. He then absorbs the carbonic acid by the use of a concentrated solution of potash, by which a very near approach to a vacuum is produced. The meat is removed from the vessel after three days, and may be kept sound without further trouble, but it will have lost 20 per cent. of its weight.

The keeping of meat by refrigeration is practised on a small scale in every household. The same thing was done on a large scale at Melbourne in 1872, when a large quantity of meat was kept for six weeks perfectly fresh in an ice-chamber. In the following year an attempt was made to ship from Australia to England meat kept fresh by the same method, but the experiment failed. Better success has attended later shipments of meat from Canada to London, and from Texas to New Orleans. The progress made in ice-making machines is such as to inspire great hopes of success in preserving meat by cold.

Among chemical antiseptics common salt of course holds a place. Many patents have been taken out for the employment of sulphur-fumes (sulphurous acid). Bisulphite of lime is very efficacious for the temporary preservation of meat, and has been practically tested with favorable results. Our readers need not be reminded of what is claimed for salicylic acid. Among other chemical agents employed for this purpose we may mention acetate of potash and chloralum.

The expulsion of atmospheric air from vessels containing meat, by means of heat, is certainly the most successful method of preservation yet adopted. Many difficult processes are in use, but the main principle—expulsion of air by heat—is the same in all. They all, too, agree in this, that they render the meat comparatively insipid.

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## NOTES.

The subject of iterated nesting by birds being under discussion in *Forest and Stream*, Dr. Charles C. Abbott contributes to that journal the following list of birds which he has himself observed nesting twice in summer: 1. Usually breeding twice—robin, catbird, bluebird, house-wren, yellow warbler, English sparrow, bay-winged bunting, chipping-sparrow, song-sparrow, orchard oriole; 2. Occasionally breeding twice—white-breasted nuthatch, scarlet tanager, yellow-bird, chewink, Baltimore oriole, purple grakle.

The American Metrological Society has, through its president, memorialized Congress for the preparation of coins, of metrical weight and uniform fineness, and for the passage of laws and conclusion of treaties whereby such coins shall become legal tender, according to their weight.

A crucial experiment was recently made at Sunderland, England, on a fire-proof house. One of the rooms was filled with tar-barrels, wood, and other combustible material, and, when the door was shut, the mass was set on fire. It simply burnt itself out, without apparently affecting the condition of the adjoining rooms or the stability of the house itself. The building material was a concrete of cement and fibre bound together by strings of iron and wire. This becomes a sort of stone-cloth, available for floors and doors, as well as walls and ceilings, so that no wood whatever need be used.

A SMALL pike caught by Dr. Charles C. Abbott, of Trenton, New Jersey, seemed to be unusually corpulent, so the fish was dissected. It was found to contain a large mud-minnow; within the minnow was a pike about two inches long, and within the pike the remains of another mud-minnow!

THE action of sundry drugs on the liver has been experimentally studied by Drs. Rutherford and Vignal, the result going to show that podophylline, aloes, and colchicum, are powerful hepatic stimulants. The same property, but in an inferior degree, is possessed by rhubarb, senna, taraxacum, and scammony. Croton-oil appears to have but little action on the liver. In three cases out of four calomel had no action on the liver, and in the fourth the secretion of bile was slightly increased.

THE *Lancet* publishes a list of British physicians deceased last year at an advanced age. There are nineteen names in the list, and the sum of their ages amounts to 1,617 years, showing an average age of eighty-five years. The greatest age attained by any of the deceased was ninety-six years, and three had reached that term. The lowest was seventy-six years, at which age two of the deceased ended their career.

THE *Monthly Weather Review* of the Signal-Office records the following phenomena for December, 1875, namely: Dandelions in bloom at Brownsville, Pennsylvania, on the 23d; 24th, pinks and hyacinths in bloom at Brookhaven, Mississippi; 25th, peach-trees in bloom at New Orleans; 31st, peach and cherry buds swelling at Litchfield, Michigan, and on the same day roses in bloom at Green Springs, Alabama.

As mentioned in the Notes of the November number, the Abbé Moigno, of Paris, has published several papers by Tyndall, Huxley, Du Bois-Reymond, and others, accompanying them with refutations of their authors' freethinking arguments. The good abbé doubtless meant well, but the Roman "Congregation of the Index" finds in his book more poison than antidote, and accordingly forbids it to be circulated.

EARTHQUAKE-SHOCKS are stated in the *Monthly Weather Review* to have been felt on December 3d at Carson City, Nevada (slight); 13th, at Maricopa Wells, Arizona; 21st, at Santa Barbara, California; 22d, at Fortress Monroe, Virginia; also at New Market, Indiana; Greensboro, North Carolina; Petersburg, Virginia; and other points in Virginia, Maryland, and North Carolina.

A COMMITTEE of the Boston Society of Civil Engineers has drafted a form of petition to be addressed to Congress, asking for the establishment of the metrical system of weights and measures in this country. This system is now in use in all European countries except England, Norway, Sweden, Russia, and Turkey. It has also been adopted in Mexico and the various states of South America.

THE Royal College of Surgeons, of England, having been advised by eminent counsel that the terms of their charter require them to admit women as candidates for their diploma, have announced that they are now ready to admit women to the examinations, on the same conditions as men.

THE repugnance of the Chinese to railroads is based upon an article of their religion—ancestor-worship. Constructors of railroads pay no respect to ancient burying-places, but run their lines right through them, thus disturbing the repose of the dead. This disregard of the sacredness of the last resting-place of the departed grievously scandalizes the devout Chinaman.

CYNODRAKON MAJOR is the name proposed by Prof. Richard Owen for a reptile having some points of mammalian resemblance, some fossil bones of which have been found in the late palæozoic or early mesozoic formation of South Africa. Prof. Owen thinks he recognizes in these fossils some indications of retrogression rather than progression in descent. A problem is here presented for which, in Owen's opinion, neither the Lamarckian nor the Darwinian theories offer any answer.

WE learn from the *American Naturalist* that a summer School of Biology will be held in the Peabody Museum at Salem, Massachusetts, beginning July 7th, and continuing six weeks. Special attention will be given to marine botany and zoölogy. Mr. J. Robinson will be instructor in botany, with C. H. Higbee as assistant. A. S. Packard, Jr., with the assistance of J. S. Kingsley and S. E. Cassino, will give instruction in zoölogy. Special instruction in microscopy by Rev. E. C. Bolles. The number of pupils is limited to fifteen.

FURTHER experiments with salicylic acid, made by Feser and Friedberger, show that it may be administered for a long time, in small doses, to domestic animals, without injurious effects to digestion, nutrition, or general health. But, given to a dog in the proportion of one gramme to five kilogrammes of the animal's weight, salicylic acid causes paralysis of the extremities and disorder of the respiration and circulation. Death from strong doses of the acid results from paralysis of the respiration.

The Normal (Illinois) "School of Natural History" will open on July 25th, continuing in session till August 25th. The course of study embraces comparative anatomy of vertebrates; comparative anatomy of invertebrates; analytical zoölogy; analytical entomology; botany. In the list of instructors are the names of B. G. Wilder, Cyrus Thomas, and J. A. Sewall. Fuller information given by S. A. Forbes, Normal, Illinois.

In the *American Journal of Science* for February, Prof. J. D. Dana corrects an error which for many years has circulated in geographies, gazetteers, and similar works. This error consists in representing the West and East Rocks near New Haven as being the termination of the Green and White Mountains respectively. "The fact is," writes Prof. Dana, "that East Rock is but a short appendage to the system of trap-dikes of the Connecticut Valley, and West Rock, a southern portion of the same system. The Green Mountains," he adds, "consist of metamorphic rocks, and are not younger than Silurian. But the trap ridges of the Connecticut Valley belong to the valley, and are of Jurassic origin."

A station for agricultural experiments has been established at the Wesleyan University, Middletown, by the State of Connecticut. Dr. Atwater, Professor of Chemistry in the university is the director, and Dr. W. C. Tilden, with two assistants, is the acting chemist. The State appropriation being insufficient to defray all the expenses of the station, the proprietors of the *American Agriculturist* have agreed to make up the deficiency.

The twin-steamship Castalia, which during four months of last year daily made voyages between Dover and Calais, appears to have given satisfaction in every respect, save speed. Arrangements have now been made by the Channel Steamship Company for the building of a large twin-steamship, which, uniting all the advantages of the Castalia with such improvements as experience has suggested, will have a speed of not less than fourteen knots an hour.

A wonderful case of recovery from a gunshot-wound was that of the late Commander Sanders of the British Navy, who died last February, at the age of ninety-one years. In 1803 he was shot in the head, the bullet passing clear through from ear to eye. He was kindly cared for by the surgeon of the French ship which he was attempting to "cut out" when he received the wound. At the end of five years' detention as a prisoner of war, he went back to England sound and well, with the exception of the loss of an eye.

The relative strength of various substances is stated as follows in the *Scientific American:* A rod ¼ inch in diameter, of the best steel, will sustain, before breaking, 9,000 lbs.; soft steel, 7,000 lbs.; iron wire, 6,000 lbs.; good iron, 4,000 lbs.; inferior bar-iron, 2,000 lbs.; cast-iron, 1,000 to 3,000 lbs.; copper wire, 3,000 lbs.; silver, 2,000 lbs.; gold, 2,500 lbs.; tin, 300 lbs.; cast-zinc, 160 lbs.; cast lead, 50 lbs.; milled lead, 200 lbs.; box or locust wood, 1,200 lbs.; toughest ash, 1,000 lbs.; elm, 800 lbs.; beech, cedar, white-oak, pitch-pine, 600 lbs.; chestnut and maple, 650 lbs.; poplar, 400 lbs.

A new variety of bronze, containing manganese, and known as "manganese bronze," has lately been introduced in England. It is said to be very valuable for all kinds of small work wherein gun-metal is now used, and it is capable of being forged like iron.

During a visitation of extreme cold weather in the vicinity of Carson River, the quicksilver pump in the Eureka mill ceased to perform its proper functions; the machinery of the pump continued to work, but no quicksilver was raised. On examination, the mercury in the tank was found to be frozen solid.

The British Geological Society has this year awarded to Prof. T. H. Huxley its Wollaston Medal. Prof. Huxley has also been elected a Corresponding Member of the Danish Academy of Sciences. The Royal Academy of Rome has conferred a similar honor upon Mr. Herbert Spencer, having elected him a Corresponding Fellow.

Prof. D. S. Jordan, of Indianapolis, will conduct a summer School of Science, during the coming season, in the mountains of East Tennessee. The members of the school will collect specimens of the birds, reptiles, fishes, insects, and plants, of that region.

In a cave near Thayngen, Switzerland, Conrad Merck has discovered a quantity of animal remains, consisting of bones of the reindeer, cave-lion, mammoth, woolly-haired rhinoceros, urus, glutton, and other species. Relics of human habitation have also been found in great abundance—such as flint-flakes, implements of reindeer-horn, and several well-executed engravings on bone, horn, and lignite.

A writer in the *Gardener's Monthly* states that, when properly cured, the kernel of the American walnut is white and delicious, with a delicate flavor hardly surpassed by any nut. The nuts should be gathered as soon as they are ripe, and not allowed to remain in the hull. They should then be dried quickly.

BENJAMIN THOMPSON (COUNT RUMFORD).

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# LINGUAL DEVELOPMENT IN BABYHOOD.[1]

BY H. TAINE.

THE following observations were made from day to day and taken down on the spot. The subject of them was a little girl, whose mental development took the ordinary course, being neither precocious nor the reverse.

From the first, probably by reflex action, this child cried incessantly, kicked, moved all its limbs, and perhaps all its muscles. It was also doubtless by reflex action that, during the first week, she moved her fingers, and even grasped for some length of time the finger of another person. Toward the third month, she began to touch with her hands, and to stretch out her arms, but did not yet know how to guide her hand; she essayed movements of the anterior members, experiencing the consequent tactile and muscular sensations—nothing more. In my opinion, out of this enormous multiplicity of movements, continually repeated, will be separated, by gradual selection, intentional movements having an object and attaining it. During the last fifteen days (age, two and a half months) I have observed one movement which is plainly an acquired one: on hearing its grandmother's voice, the infant turns its head in the direction from which the sound proceeds.

There is the same spontaneous training for the use of the voice as for movements. The vocal organ acquires dexterity just as the limbs do. The child learns how to produce such or such a sound just as it learns how to turn the head or the eyes, i. e., by constant efforts.

Toward the age of three months and a half, while in the country, the child was brought into the open air, and laid upon a carpet spread in the garden. Here, lying on her back or on her face, she for hours at a time would work with all her limbs, uttering a multitude of differ-

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[1] Translated from *Revue Philosophique* by J. Fitzgerald, A. M.

ent cries and exclamations, consisting exclusively of vowel-sounds; this continued several months.

By degrees consonants were added to the vowels, and the exclamations became more and more articulate. This process resulted in a sort of prattle of great diversity and completeness, which would be kept up for a quarter of an hour at a time, and repeated ten times a day. The sounds (vowel and consonant), which at first were vague and very hard to discriminate, became more and more like those uttered by adults, and the series of simple cries came to be, in some measure, like a foreign language which we do not understand. The infant is pleased with its prattle, like a bird; one can see that she is happy—that she smiles with pleasure—yet it is nothing better than the chirruping of a bird as yet, for the child does not attach any meaning to the sounds she utters. (Age, twelve months).

She has acquired thus much, in great measure, by her own endeavors and unassisted, but she has gained a little by the aid of others and by imitation. First, of her own accord she produced the sound *mm;* this amused her—it was for her a discovery. So, too, she of herself produced another sound, *kraaau*, emitted from the windpipe in deep gutturals. These two sounds were repeated several times in succession in the hearing of the child; she would listen attentively, and now she repeats them at once on hearing them. The same is to be said of the sound *papapapa*, which she at first uttered several times at random and by herself, and which was then repeated to her a number of times, in order to fix it in her memory. She soon uttered this sound at will, with easy, unerring execution (though without understanding what it meant), as simple prattle. In short, example and education have served only to call the child's attention to sounds which she herself was already attempting to make; to direct her preference to these, to make them uppermost among the host of similar sounds. But the initiative all came from herself; and the same is to be said with respect to gesture. For months she of her own accord attempted all the movements of the arms, flexion of the hand at the wrist, bringing the hands together, etc. Then, after instruction and repeated effort, she learned to clap hands, to hold up the two hands, as in the gesture of astonishment, etc. Example, instruction, and education, are only channels in the bed of which the stream flows; its source lies higher.

To see that this is the case, one has only to listen to her prattle for an hour: it is wonderfully flexible. I am satisfied that here every shade of emotion—surprise, joy, vexation, sadness—finds expression in varieties of tone; herein she equals or even surpasses the adult. On comparing her with animals, even those best endowed in this way—such as the dog, parrot, singing-birds—I find that, with a less-extended gamut of sounds, she far surpasses them in the fineness and the abundance of her expressive intonations. Delicacy of impressions and delicacy of expressions are the distinctive characteristics of man as compared with animals: here is the origin of language and of general ideas. Among animals, man is, what some great and ingenious poet is among laborers and peasants: in a word, he is cognizant of a multitude of shades and tints, even to a whole class of shades, which are unnoticed by them. This is further seen both in the kind and in the degree of man's curiosity. It is easily seen that, commencing with the fifth or sixth month, infants, during the succeeding two years or more, give all their time to making experiments in natural philosophy. There is no animal, not even the cat or the dog, which makes such continual study of all bodies within its reach. Every day, the infant of whom I speak (age twelve months) touches, feels, turns over, lets fall, tastes, and experiments upon, whatever comes under its hand; whatever the object may be—a ball, doll, rattle, toy—once it is sufficiently known, the infant leaves it alone: it is no longer a novelty; there is nothing more to be learned from it; it no longer interests the child. This is simple curiosity; the child's physical wants, its desire of food, have nothing to do with the matter. It would seem as though already in its little brain each group of perceptions tends to complete itself, as in the brain of a child that possesses language.

She does not yet pronounce any word to which she attaches a meaning, but there are two or three words to which she attaches a meaning on hearing them uttered. She daily sees her grandfather, whose portrait, far less than life-size, but a very good likeness, has often been shown to her. During the past two months or so (from the age of ten months), when any one asked her the question, "Where is grandfather?" she turns to the portrait and laughs at it. Before her grandmother's portrait, which is not so good a likeness, she makes no such gestures, nor does she give any token of knowing what it is. For a month past (from the age of eleven months), whenever she is asked, "Where is mamma?" she turns toward her mother. So, too, with her father. I would not go so far as to affirm that these three actions transcend animal intelligence. A little dog, who sits by my side, in like manner understands what is meant when he hears the word *sugar:* he will come from a distance to get his morsel. In all this there is nothing but association: in the case of the dog, between a sound and a certain taste-sensation; in that of the infant, between a sound and the shape of an individual face; the object designated by the sound is not yet a general character.

I believe, however, that now (age, twelve months) a step farther has been taken; witness the following circumstance, which for me is decisive: This winter the child was daily taken to her grandmother's, and the latter very frequently showed her a copy, in colors, of a painting by Luini representing a nude Infant Jesus. On showing her this picture she was told that "this is baby." During the last eight days, whenever, in some other room, we ask her, "Where is baby?"

(meaning herself), she turns toward any picture that may be there, whether it be a painting or an engraving. Hence "baby" signifies, for her, some general notion, whatever paintings and engravings of persons or landscapes may possess in common; i. e., if I am not mistaken, "baby," in her mind, signifies *something variegated in a shining frame.* Indeed, it is plain that the objects painted or designed within the frames are so much Greek to her, while she must be deeply impressed by the glittering frame and the patches of color, light, and shade, within its border. Here, then, we have her first general term; the meaning she gives it is not ours, but nevertheless it is evidence of original work done by the infantile understanding. For, though we have supplied the word, we have not supplied the meaning.

(Age, fourteen months and three weeks.) The gains of the last six weeks have been notable: besides the word "baby" she now understands several others, and of these she pronounces five or six, giving to each a meaning of its own. Mere prattle is succeeded by a beginning of intentional and determinate language. The principal words pronounced by her now are *papa*, *maman*, *tété* (by which she means *nurse*); *oua-oua* (her term for *dog*), *koko* (hen, cock), *dada* (horse, wagon), *mia* (cat, kitten), *kaka*, and *tem.* She acquired earliest the two words *papa* and *tem:* this latter word is very curious, and well worthy of serious consideration.

For fifteen days she pronounced *papa* without a purpose, without a meaning, as simple prattle, and as an easy and amusing exercise of articulation. Later came association between this name and the image or perception; and then the portrait or the person of her father brought to her lips the sound *papa*, and this same word, when pronounced by another, awoke in her the memory, the mental image of her father. Between the two states just noticed there exists an insensible transition, so that, at certain times, the first state still persists after the second state has been attained; at times she still plays with a sound, though she understands its sense. This is very easily seen with respect to some of her later acquisitions, for instance the word *kaka.* This word she often repeats without purpose or intent, as prattle, much to the displeasure of her mother. Again, she frequently utters the word purposely, when occasion offers. Further it is evident that, as in the case of the word "baby," she has extended the meaning of this term. Thus, for instance, on seeing in a flower-bed the track of moistened earth left by a watering-pot, she repeated this word again and again with evident appreciation of its meaning. For her it signifies *what wets.*

She shows great capacity for imitating sounds. She has seen and listened to fowls, and now repeats their *koko* far more accurately than we can do it, with the guttural intonation of the animals themselves. This is simply a faculty pertaining to the windpipe, but she possesses another faculty which is far more striking, a faculty that is *par excel-*

*lence* human, namely, the power of noting analogies. This is the fountain-head of general ideas and of language. We point out to her on the walls of a room the figures of birds painted red and blue, a couple of inches in length, saying once only, "Look at the kokos." She was at once conscious of the resemblance, and for half a day she took the liveliest pleasure in being carried up and down along the walls of the room, enthusiastically crying out, at the sight of each bird, *koko!* No dog, no parrot would ever act thus, and, in my opinion, we have in this fact the essence of language. Other analogies she perceives with equal readiness. The first dog she ever saw was a little black one belonging to the house, who barks frequently; from him she framed the word *oua-oua.* Very soon, with but slight assistance from those around her, she applied this word to dogs of all sizes and of every breed that she saw in the street; later she applied it to porcelain figures of dogs—a still more noteworthy fact. Nay, on seeing, day before yesterday, a month-old kid, she called it *oua-oua*, thus naming it after the dog, which is the nearest form, rather than after the horse, which is too big, or the cat, which has a different gait.[1] Herein we perceive a trait characteristic of man: two very dissimilar successive perceptions leave a common residue, a distinct impression, solicitation, impulsion, which results in the invention or adoption of some mode of expression, either by gesture, cry, articulation, or name.

I come now to the word *tem*, one of the most noteworthy and one of the first pronounced by her. All the other words are probably *attributives*, to use the language of Max Müller,[2] and a person has no difficulty in discovering their meaning; this is probably a *demonstrative*, and, as we had no term with which to translate it, we took several weeks to discover its meaning.

At first, and for more than two weeks, the child pronounced this word *tem* as she did the word *papa*, without giving to it any precise meaning; she thus practised dental articulation followed by a labial, and the thing afforded her some amusement. By degrees the word became associated in her mind with a definite intention, and at present it means for her *give*, *take*, *see*, *look.* She pronounces it very perfectly, several times in succession, and with earnestness, her aim being now to get some new object which she sees, again to have some one take her up, or to attract attention to herself. All these meanings are comprised in the word *tem.* It may be that it is a form of the word *tiens*, which had often been addressed to her in a somewhat similar sense. But I am rather inclined to suppose that this word was coined by herself to express her principal desires, viz., to be taken in

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[1] When the Romans first saw the elephant they called it the *Lucanian ox.* Thus, too, savage tribes that had never before seen a horse gave that animal the title of *big hog.* (*See* Müller's "Lectures on Darwin's Philosophy of Language.")

[2] Lectures on the "Science of Language," sixth edition, vol. i., p. 309.

the arms, to get the objects she wants, and to attract notice. If such is the case, then this word is a *natural vocal gesture*. This view is rendered more probable by the fact that she possesses other words, of which more anon, and which are evidently the products, not of imitation, but of invention.

(Fifteenth to seventeenth month). Great progress made; the child has learned to walk, and even to run. She is gaining new ideas every day, and understands a number of phrases, such as these: "Fetch the ball;" "Go and *doudou* to the lady" (i. e., fondle her and let her kiss you); "Come and stand between papa's legs;" "Go down there;" "Come here," etc. She is beginning to distinguish between the tone of anger and that of pleasure; she quits doing anything forbidden with severe countenance, or with voice expressive of disapproval; of her own accord she frequently shows a desire of being fondled. But she has learned or invented but few new words recently. Her chief new words are *Pa* (Paul), *Babert* (Gilbert), *bébé* (baby), *bééé* (nanny-goat), *cola* (chocolate), *oua-oua* (anything good to eat), *ham* (eating, I want to eat). There are a number of other words which she understands, but is unable to pronounce, such as grandfather, grandmother. Her vocal organs, not being sufficiently practised, do not as yet reproduce all the sounds she knows, and to which she attaches meanings.

*Cola* (chocolate) was one of the first dainties she ever tasted, and she prefers it to all others. She gets a lozenge daily during her visits to her grandmother; she knows the box in which the bonbons are kept, and keeps pointing toward it until it is opened.

*Bébé.*—We have spoken of the curious meaning she at first gave to this word; by degrees, under the influence of education, she has come nearer to its ordinary sense. Other infants have been shown to her, and called *bébé*; she herself has also been called by this name; now she answers to it. She has been shown the reflection of her own face in a mirror, and told to look at *bébé*, and now she goes herself to the glass, and, on seeing the image, laughs and calls "*bébé!*" Starting from this, she gives the name of *bébé* to miniatures, pictures, and statuettes. Here again education has produced a result that had not been anticipated: the general character perceived by the child is not the one that we could have desired her to perceive. We have taught her the sound, and she has invented the meaning.

*Ham* (eating, I want to eat).—Here she originated both the sound and the sense. This sound she first uttered during her fourteenth month. For weeks I took it to be mere prattle, but at last I noticed that it was uttered always, without exception, when food was in sight. Now she never fails to say *ham* whenever she is hungry or thirsty. This again is a *natural vocal gesture*.

*Oua-oua.*—It was not till three weeks ago (end of the sixteenth month) that she employed this word in the sense of something good to eat. For a while we did not understand what it meant, for the same sound had long been used by her, but always to signify *dog*. In this new meaning the sound has oscillated between *va-va* and *oua-oua*. In all probability the sound here written *oua-oua* is for her twofold, in accordance with the two different meanings she attaches to it. But my ear does not detect this difference. The senses of infants, which are less obtuse than ours, perceive delicate shades which we do not distinguish. It is worthy of mention that she strictly applies this term *oua-oua* to food and drink; the act of eating or drinking is expressed by *am*, or *ham*. Thus, when she hears the dinner-bell, she says *am*, not *oua-oua;* but at table, when seated before some article of food, she says *oua-oua*, and much less frequently *am*.

On the other hand, the word *tem* (give, take, look), of which I have already made mention, has during the past two months fallen into desuetude. She never pronounces that word now, nor can I find that she has replaced it by any other. Doubtless the reason of this is, that we did not care to learn it: it answered to none of our ideas, inasmuch as it coupled three very distinct notions.

On summing up the facts already stated we reach the following conclusions; it remains for others to modify them by observing other infants:

At first the infant cries, and employs its vocal organ in the same way as its limbs, spontaneously and after the manner of reflex action. Spontaneously, too, and because it finds pleasure in being active, the infant later exercises its vocal organs in the same way it exercises its limbs, gaining the perfect use of them by repeated essays and by a process of selection. From inarticulate it thus passes to articulate sounds. The variety of intonations which it acquires evinces in the child great delicacy of impression and of expression; hence the faculty of forming general ideas. All we do is to aid it in grasping these ideas by suggesting our words. To these the infant attaches ideas of its own, generalizing after its own fashion rather than ours. Sometimes it invents not only the meaning of a word, but the word itself. Several vocabularies may succeed to one another in its mind, new words obliterating old ones; several different significations may successively be attached to one word; several words invented by itself are natural vocal gestures; in short, it learns a ready-made language as a true musician learns counterpoint, or as a true poet learns prosody: the child is an original genius, which adapts itself to a form built up bit by bit by a succession of original geniuses. If there existed no language it would discover one, or find an equivalent.

This series of observations was interrupted, owing to the misfortunes of the year 1870. The following notes may serve to show the mental state of an infant: in many respects this state is that of primitive peoples in the poetical and mythological period

A water-jet, which this infant saw daily for three months, always gave her new pleasure. The same is to be said of the flow of a river as seen from a bridge. The flashing, running water was plainly for her an object of extraordinary beauty, and she would keep exclaiming, "Water, water" (age, twenty months). A little later (thirty months) she was profoundly impressed on seeing the moon. She wanted to look at it every night. When she walked abroad it seemed to her that the moon also was moving, and this discovery gave her delight; as the moon made her appearance in different localities, according to the hour, being seen at one time in front of the house, and again in the rear, she would exclaim, "Another moon! another moon!" One night (age, three years) she wanted to know where the moon was, and, on being told that it had gone to bed, she asked, "Where, then, is the moon's nurse?" All this very closely resembles the emotions and conjectures of childlike races; their profound wonderment in presence of the great phenomena of Nature; the influence exerted upon them by analogy, language, and metaphor, leading them to form myths of the sun, the moon, etc. Suppose such a state of mind to be universal at any period, and we can readily foresee what religious ideas and legends would be the result; in fact, we have instances of this process of development in the Vedas, the Edda, and even in Homer.

If we speak to the child of an object at some little distance, but which she can represent to herself definitely enough, having seen the object itself or something like it, her first question always is: "What does it say? What does the rabbit say? What does the bird say? What does the horse say? What does the big tree say?" Whether it be an animal or a tree, she always treats the object as a person; wants to know what it thinks, what it says. By a spontaneous induction, she pictures it as like herself or like us—humanizes it. This same tendency is found among primitive races, and it is all the stronger the more primitive they are.

It requires long time and many an effort for the infant to attain to ideas which to us appear simple. When this child's doll had its head broken she was told that now the doll was dead. One day her grandmother said to her: "I am old, and shall not remain long with you; I shall die." "Your head will be broken, then." This she repeated several times. Even yet (age, three years and one month), to be dead means, for her, tô have a broken head. Day before yesterday a magpie that had been killed by the gardener was tied to the top of a pole for a scarecrow; on being told that the pie was dead the child wished to see it. "What does the pie do?" she asked. "She does nothing; she will never stir again, she is dead." "Oh!" For the first time the idea of final immobility has entered her mind. Now let us suppose a people to stop at this idea, and to have no other definition of death than this. For them the Beyond will be the Sheol of the Hebrews—the place where the motionless dead live a vague sort of life. For her *yesterday* means *in the past*, and *to-morrow* means *in* *the future;* neither of these terms signifies for her just one day. Here, again, she gives too large a signification to words. And an infant scarcely employs a single word that is not destined later to receive a more restricted meaning. Like primitive peoples, infants incline to conceive large and general ideas. The child presents, in the transitional state, mental characters which we find in the fixed state in primitive civilizations, just as the human embryo presents in the transitional state physical characters which are found in the fixed state in certain lower classes of animals.

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# NATURAL TRUMPET OF THE CRANE.

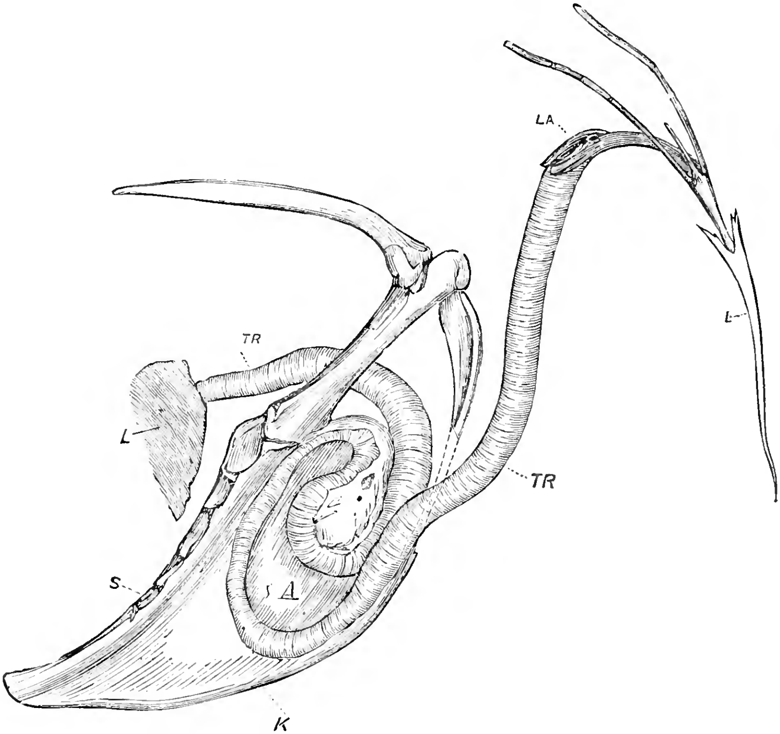
By FRANK BUCKLAND.

SPORTSMEN and naturalists, both at home and abroad, would do well to collect not only the skins of birds, but also to search for any peculiarity which may happen to occur in their internal structure, especially the bones and the larynx.

Some weeks since, when calling upon my friend Mr. Jamrach, the animal-dealer, I observed in the back-yard, on the dust-heap, a number of dead birds. Among them was the body of a very large crane. Mr. Jamrach allowed me to take this home, and I made several preparations of it. We now figure the very remarkable trachea, or windpipe, of this bird. In an ordinary bird, such as a chicken, when cutting open the skin of the throat, it will be found that the trachea forms a continuous tube, going in a direct line from the mouth to the lungs, where it bifurcates. In the crane this is not the case. Instead of passing between the two bones ordinarily known as the merry-thought, it becomes convoluted in a very remarkable manner. If this convolution had been placed immediately under the skin, first of all it would have been cumbersome to the bird; and, secondly, there would have been a great likelihood of its becoming injured. The breastbone, therefore, has been hollowed out in the middle in such a manner as to keep the trachea packed up in a beautiful box of bone. Inside this box of bone there are about thirteen inches of the trachea. The trachea enters this bony box at its lowest margin; it then runs along the bottom and ascends to the top; then takes a very sharp turn, and again descending to the bottom of the box joins the lungs in the usual way. In life this trachea is not fixed in the box, but is capable of extension and prolongation; in fact, is almost as elastic as India-rubber.

The diagram will explain this.

The curious cartilaginous-like material—reminding us of mosaic work—of which the trachea is composed, differs much in pattern in its various portions, the rings being single near the mouth, while a few inches farther they appear to be double. A model of them at this part of the tube can be obtained by locking the fingers of both hands one into the other. Just as the trachea leaves the bony box it is considerably enlarged.



*T* is the tongue, attached to the bifurcated hyoid bone; *LA* is the larynx; *TR* is the trachea immediately before it buries itself in the peculiar hollow box of bone, *A*. In this box, as already described, it becomes convoluted; then, leaving the box, it enters the cavity of the chest, and joins the lungs at *L*.

Of course, the use of this curious structure is to produce those wonderful sounds which are peculiar to the crane. In fact, it is a portion of a *cornet-à-piston* or trombone, and is, no doubt, worked by some very delicate muscles. I have never had the pleasure of seeing cranes fly in the air, but I am told that the noise they make is very wonderful. We read: "Cranes range, according to the season, from the north of Europe to the south of Asia, and north of Africa, and in the latter country they are said to extend their migrations as far as the Cape of Good Hope. On these excursions they fly high in the air, though they experience some difficulty in getting on the wing from the ground. Before taking their spring they run some paces, raise themselves a little at first, and then unfold a powerful and rapid wing. In the air they form very nearly an isosceles triangle, possibly for the purpose of cutting the element with greater facility. When attacked by an eagle, or the wind is likely to break their order, they close in circles. Their passage frequently takes place during the night, which is known by their sonorous voice, which announces it; and the head of the troop often utters, to indicate the route he is taking, a cry of appeal to which all his followers answer. Their voices, even on these nocturnal voyages, are exceedingly loud—probably owing to the length of the windpipe and the convolution near its bronchial extremity. When they cry during the day they are generally understood to forebode rain, as is the case with the cries of many other birds which feed partially on those worms which the approaching humidity brings to the surface—not only when the rain actually falls, but when, from the changed state of the air, the evaporation is much diminished. When they are peculiarly noisy and tumultuous, and fly near the ground, occasionally alighting, it is considered as a pretty certain indication of a tempest. On the other hand, when they rise high, and fly onward in regular order, it is regarded as a sign of fine weather."

That great observer, Virgil, has used the simile of cranes in flight in a grand passage in the tenth "Æneid," to give an idea of the Greeks and Trojans charging each other in the battle-field:

". . . . Clamorem ad sidera tollunt
Dardanidæ e muris: spes addita suscitat iras:
Tela manu jaciunt. Quales sub nubibus atris
Strymoniæ dant signa grues atque æthera tranant
Cum sonitu, fugiuntque Notos clamore secundo."

[The Trojans, from their walls, raise acclamations to the stars. Additional hope rouses up their fury. Darts from their hands they hurl, as under the black lowering clouds Strymonian cranes give the signal and swim along the skies with obstreperous din, and from the stormy south winds with joyous clamor fly.]

I consider the marvelous natural trumpet of the crane to be a most beautiful provision given by the Creator to these wild birds to enable them to keep their ranks, and not lose each other when migrating. In fact, we men have adopted the idea by using trumpets. It often happens that the dust at a field-day is so great that very little can be seen, while it would be impossible for the human voice to be heard; trumpets, therefore, come in here of the greatest service, especially to direct movements of cavalry. In the same way, the cranes might possibly lose each other when flying in the wilderness of space of the vast firmament of ether, and, were it not for their being able to signal to each other, they would be unable to travel with facility either at night, or when passing through clouds and fogs.

A few days since a valued correspondent in Ireland sent us the breastbone of a Hooper swan. I have dissected this, and find the trachea convoluted in a manner very similar to that of the crane.

There is a legend that when a swan is dying he becomes musical.

The origin of this legend probably is the trumpeting of the wild-swan. This our friends can hear in the Zoölogical Gardens; it is a melancholy sound, and may be thus written—"hwoo hwoo." The tame swan has not this structure of the windpipe, showing, therefore, that it is a distinct species. As the trumpet is useful to the crane, so also is it to the swan. They fly very high, in order that the "hawks should not gain the sky" of them; they always fly with the wind, and when going with a stiff breeze are said to go at a pace of a hundred miles an hour.

Many of our friends have probably heard that amusing bird, the trumpeter (*Cariama cristata*). Mr. Cholmondeley, of Condover, has a very tame specimen, that wanders all over his house, and goes out walking in the garden with him. In the trumpeter-bird there is a musical apparatus of another kind. The note of the trumpeter is very agreeable to the ear.

I have lately dissected a Merganser. I find that his trachea is also peculiar: it swells out considerably about the third of its way down, and at the end it bulges out into a box as large as a walnut. The common duck has a curious larynx. At the bottom of the windpipe will be found a bony dilatation. Our readers should examine this for themselves. The female has not this peculiarity, and, strange to say, although the drake has this very peculiar organism, he is not able to quack—the females only quack; the males give a short hiss. My friend Mr. Bartlett informs me that on one occasion a gentleman sent him this bony box, which the cook had taken out, and said that it was the ossified heart of a duck.—*Land and Water.*

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# PETROLEUM.[1]

### By Prof. H. B. CORNWALL.

ALTHOUGH it has only lately acquired its present important place among articles of commerce, this valuable product of Nature's laboratory has been known for ages, and was used for medicinal and illuminating purposes in ancient times. The petroleum-spring of Zante, one of the Ionian Islands, was mentioned by Herodotus more than 2,000 years ago; and Pliny says that the oil of a spring at Agrigentum, Sicily, was used in lamps. The city of Genoa was formerly lighted from the wells of Amiano, in Parma, Italy.

Prof. A. E. Foote (*American Chemist*, November, 1872) states that Peter Kalm, in his "Travels in North America," published in 1772, gives a map of the Pennsylvania oil-springs in 1771; but, according to H. E. Wrigley, the earliest mention of petroleum in that State

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[1] Petroleum, literally *rock-oil*, from *petra*, rock, and *oleum*, oil.

occurred in the report of the commander of Fort Duquesne, 1750, when he witnessed the ceremonies of the Seneca Indians on Oil Creek. A prominent feature of the ceremonies was the burning of the oil as it oozed from the ground.

The oil-spring of Cuba, Alleghany County, New York, called the Seneca Oil-Spring, was described by Prof. Silliman, in 1833, as a dirty pool, about eighteen feet in diameter, covered with a film of oil, which was skimmed off from time to time for medicinal purposes. The so-called Seneca-oil was not from this spring, but from Oil Creek. Hildreth, in 1833, gave an account of the salt-wells of the Little Kanawha Valley, West Virginia, which he says yielded a little oil. In 1840 a well at Burkesville, Kentucky, was described as spouting oil at the estimated rate of seventy-five gallons a minute for a few days, but it then failed entirely (Dana, "Mineralogy," fifth edition, 1869). In 1844 Mr. Murray mentioned the petroleum of Enniskillen, Canada.

About twenty years ago the manufacture of oil from coal and bituminous shales, having been widely extended through the labors of Abraham Gesner and James Young, of Glasgow, began to excite interest in this country, and, according to S. D. Hayes, the first coal-oil offered for sale in this country was made by Philbrick & Atwood, in 1852, at the works of the United States Chemical Manufacturing Company, Waltham, Massachusetts. It was called coup-oil, after the recent *coup d'état* of Louis Napoleon, and was used as a lubricator.

In 1856 the first illuminating oil was made by Mr. Joshua Merrill, from Trinidad bitumen, according to the same authority. According to H. E. Wrigley, however, a refinery was started as early as 1850 by Mr. Samuel Kier, of Pittsburg, Pennsylvania, for the treatment of crude petroleum ("Report on Petroleum of Pennsylvania" for the "Second Geological Survey of Pennsylvania, 1874"). Success being limited only by the small amount available, search for the oil was naturally directed to Oil Creek, and in 1858 Messrs. J. G. Eveleth and George H. Bissell, of New York City, leased one hundred acres of land near Titusville, on the northern border of Venango County, Pennsylvania, and engaged Colonel E. L. Drake, of New Haven, Connecticut, to bore a well. On the 28th of August, 1859, he struck oil at a depth of seventy-one feet (according to some authorities sixty-nine and a half feet), and a pump was adjusted which produced twenty-five barrels a day.

In 1861 the first flowing well was struck by Mr. Funk, on the M'Elhenny Farm, Oil Creek, at a depth of 400 feet. Soon after two more wells were sunk (the Phillips and Empire), flowing 3,000 barrels each daily. Since 1858, in round numbers, 10,500 wells have been bored in Pennsylvania, and oil-wells also exist in West Virginia, Ohio, Kentucky, and elsewhere, with results that will be stated hereafter.

It would not be proper to leave the history of petroleum without mentioning Prof. B. Silliman's report on Pennsylvania petroleum to Messrs. Eveleth, Bissell & Reed, 1855.

He examined the rock-oil or petroleum of Venango County, and, long before the present processes of refining had been introduced, suggested several very important processes, which have been since followed in its treatment; such as distillation by steam, "cracking," or breaking up of the heavier oils into lighter compounds, its use for making gas, for illuminating purposes, for lubricating, etc.

COMPOSITION.—Petroleum is a mixture of several hydrocarbons, and contains also bituminous materials, sulphur, carbonaceous matter, sand, and clay. Its odor is generally offensive. The color and specific gravity vary greatly. The crude petroleum of Pennsylvania is generally dark-green with a brownish tinge by reflected light; the color of thin layers by transmitted light varies from dark-yellowish to reddish-brown. The oil of Enniskillen is blackish-brown; of Mecca, Ohio, yellow; in the neighborhood of Shamburg, Venango County, Pennsylvania, "black" and "green" oils occur side by side in the same districts; the lubricating oil of White Oak, West Virginia, is yellow; that from Amiano, Italy, is red to straw-color; at Baku the light oil is clear and faint yellow. Pennsylvania petroleum is somewhat thick, like thin sirup, but, although stiffened somewhat by cold, is always fluid. The oil of Pagan, Burmah, is very light, resembling naphtha, as is some of that from Baku.

The specific gravities of different petroleums are as follows: White Oak, West Virginia, 28° to 40° Beaumé; Mecca, Ohio, 26° to 27°; Franklin, Pennsylvania, 30° to 32°; Cuba, New York, 32°; Tidioute, 43°; Pit-Hole, 51°; Pomeroy, Ohio, 51°; Russia, 28° to 40°. The heavy oils command, as a rule, a higher price. Although there is no certainty about their occurrence, the heavy oils have been frequently found at a higher level than the light oils in Pennsylvania, so that this was at one time supposed to be the rule.

The constituents of the mixture known as petroleum are separated from each other by fractional distillation; with care they can be isolated in quite a pure state, but in practice they undergo various decompositions, and are frequently to be regarded rather as *products* than as *educts* of the operations. Some are gaseous at ordinary temperatures, others are liquid, and others solid. They are divided into two classes: one having the formula $C_nH_{2n}+_2$, and belonging to the marsh-gas, or paraffine series; the other, with the formula $C_nH_{2n}$, belonging to the ethylene series (olefines). They have been carefully investigated by Pelouze and Cahours, Warren, Schorlemmer, and Ronalds, and the results obtained by them are given in the following table, partly compiled from the review of the subject by Prof. S. P. Sadtler, in Prof. Genth's "Report on the Mineralogy of Pennsylvania" ("Second Geological Survey, 1874"). The letters F, R, W, P and C, and S, indicate the observers, Fouqué, Ronalds, Warren, Pelouze and

Cahours, and Schorlemmer. The first and second were found by Fouqué in gaseous exhalations from petroleum-wells at Petrolia (and Fredonia, New York); the third in similar exhalations from wells at Pioneer Run.

MARSH-GAS SERIES.—FORMULA $C_nH_{2n+2}$.

| No. | NAME. | Formula. | Carbon. | Hydrogen. | Boiling-Point (C.). | Specific Grav. (0° C.). | Observer. |
|---|---|---|---|---|---|---|---|
| 1 | Methyl hydrid (methan)... | $CH_4$ | 75 | 25 | A gas. | .559 | F. |
| 2 | Ethyl hydrid (æthan)...... | $C_2H_6$ | 80 | 20 | " | | F. |
| 3 | Propyl hydrid (propan).... | $C_3H_8$ | 81.81 | 18.19 | −17° | | F. R. |
| 4 | Butyl h. (normal butan)... | $C_4H_{10}$ | 82.8 | 17.2 | 0 | .600 | W. |
| 5[1] | Pseudo-butan............ | " | " | " | 17 | | |
| 6 | Amyl h. (normal pentan).. | $C_5H_{12}$ | 83.33 | 16.67 | 37–39 | .645 | W. |
| 7 | Dimethyl-propan.......... | " | " | " | 30.2 | .626 (17°) | P. & C., W., S |
| 8 | Hexyl h. (normal hexan)... | $C_6H_{14}$ | 83.72 | 16.28 | 68.5 | .689 | P. & C., W., S. |
| 9 | Æthyl-isobutyl.... ....... | " | " | " | 61.3 | .676 | W. |
| 10 | Heptyl h. (normal septan).. | $C_7H_{16}$ | 84 | 16 | 98.1 | .730 | W., S. |
| 11 | Æthyl-amyl............... | " | " | " | 90.4 | .718 | W., S. |
| 12 | Octyl h. (normal octan).... | $C_8H_{18}$ | 84.21 | 15.79 | 127.6 | .752 | W. |
| 13 | An isomer of No. 12....... | " | " | " | 119.5 | .737 | W., P. & C. |
| 14 | Nonyl hydrid (nonan)..... | $C_9H_{20}$ | 84.38 | 15.62 | 150.8 | .756 | W. |

Pelouze and Cahours carry the marsh-gas series to $C_{15}H_{32}$, but Warren concluded that it terminates with $C_9H_{20}$, and that the oils of higher density and atomic numbers belong to the ethylene series.

On inspecting the above table it will be seen that numbers 4, 7, 9, 11, 13, and 14, have a common difference of about 30° C. between each in succession, in regard to their boiling-points; and that numbers 6, 8, 10, and 12, have a similar common difference, and are each about 8° higher in their boiling-points than the ones next below them. On this account, Warren divided them into two groups; but he included here another $C_4H_{10}$, with a boiling-point of 8 to 9°, which is, according to Sadtler, a mixture of the two given in the table.

Besides the members of the marsh-gas series given above, American petroleum yields liquids boiling above 300° C., which on cooling yield a solid mass called paraffine, white and transparent when pure. It probably is a mixture of the higher members of the series $C_nH_{2n+2}$, and on heating in a sealed tube is converted into a mixture of several paraffines and olefines of lower molecular weight, liquid at ordinary temperatures (Fownes).

Of the ethylene series, Warren has found in Pennsylvania petroleum, decylene, $C_{10}H_{20}$, boiling-point 174.9°; undecylene, $C_{11}H_{22}$, boiling-point 195.8°; and bidecylene, $C_{12}H_{24}$, boiling-point 216.2°; these have a difference of about 20° C. in their successive boiling-points.

No higher series of hydrocarbons is yet known from Pennsylvania petroleum, but members of the benzol series, $C_nH_{2n-6}$, have been found in other petroleums. Thus De la Rue and Müller, in 1856, found benzol, toluol, and xylol, in Rangoon tar; Bussenius and Eisenstuck discovered xylol in petroleum from Sehnde, Hanover; Pebal and Freund detected benzol, $C_6H_6$, toluol, $C_7H_8$, xylol, $C_8H_{10}$, cumol, $C_9H_{12}$, and cymol, $C_{10}H_{14}$, in naphtha from Boroslaw, Galicia; De la

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[1] Not yet obtained in a pure state.

Rue and Müller found naphthaline, $C_{10}H_8$, in Rangoon tar; and, finally, a member of the anthracene series, $C_nH_{2n-18}$, has been found in the last products of the distillation of petroleum for paraffine-oil. It is probably formed by destructive distillation of the petroleum, and has been called *thallene* or *viridine* by Prof. H. Morton, who investigated especially its fluorescent character.

Petroleum undergoes alteration by *evaporation of its lighter constituents*, leaving viscid or solid bitumen, containing more or less paraffine; by *oxidation of some hydrogen*, giving rise to ethylenes, benzols, or naphthalenes; and, by the additional *absorption of oxygen*, forming true asphaltum. Of this latter class are the grahamite of West Virginia and the albertite of Nova Scotia. The grahamite I believe to have been altered before reaching its present level, for reasons which cannot be given here. Mr. W. P. Jenney has made some interesting experiments on the oxygenation of petroleum and the formation of artificial oxygenated hydrocarbons resembling natural products (*American Chemist*, April, 1875).

OCCURRENCE OF PETROLEUM.—It occurs in rocks of nearly all ages, from the Lower Silurian up; most abundantly in shales and sandstones; also to some extent in limestones. Sometimes it impregnates the whole stratum; sometimes it collects in subterranean cavities and fissures. In the Rangoon and Caspian regions the oil occurs near the surface in clayey soil, and collects in shallow pits. A noted foreign locality is Ye-nan-gyoung, in Burmah, where the wells are narrow shafts, 180 to 300 feet deep, and large enough for a man to work in. The oil is drawn up with a bucket and windlass, and as many as 1,000,000 barrels are annually obtained. In Persia oil is largely found at Baku, on the west shore of the Caspian; China yields a small amount of oil; Japan has small and undeveloped districts; New Zealand, also, shows indications. In the Caucasus, Russia, surface-wells have long been worked, and lately wells have been sunk with great success. In Galicia, Austria, are wells yielding largely; and Alsace and Hanover have produced some oil. Petroleum has likewise been found in Peru, Ecuador, Southern Mexico, San Domingo, Trinidad, and Nova Scotia, in small quantities.

The petroleum district of Canada West is in Lambton, Bothwell, and Kent Counties (H. E. Wrigley), and in Ontario. The average production is not over 2,500 barrels daily. It occurs mainly in the Corniferous limestone of the Lower Devonian, but is also found in greater or less quantity in the Bird's-eye limestone of the Lower Silurian, and the Lower Helderberg limestone of the Upper Silurian. The cavities of Orthocerata in the Trenton limestone (Lower Silurian) at Pakenham, Canada, frequently hold small quantities of petroleum. In Canada East there is a petroleum district on the St. John's River, not far from Gaspé Bay.

In the United States oil is very abundant in Western Pennsylva nia, and has been found in considerable quantity in West Virginia, Ohio, Kentucky, and Tennessee. It has also been found, but in small quantities, in New York State, near Chicago, in Michigan, Indiana, Colorado, and California. The oil of Southern California comes from Tertiary shales, and is said to contain no paraffine.

The Upper Oil-Region of Pennsylvania begins in the vicinity of Tidioute, on the Alleghany, in Warren County, and runs southwest to Titusville, thence nearly south, along Oil Creek, into Venango County to Oil City, and thence southwest to Franklin. East Sandy, on East Sandy Creek, is at the extreme southeast edge of this field, and forms the only connecting link between the upper and lower oil-fields of the State. The principal points in this upper region are Tidioute, Triumph, and Economy, in the Tidioute District; West Hickory, New London; the Titusville District, including the Drake well; Church Run, Pit-Hole, Shamburg, Petroleum Centre, Rouseville (between these two places were the Blood well, of 1,000 barrels daily, and the Phillips well, which once flowed 3,940 barrels in twenty-four hours, and has produced over 500,000 barrels), Oil City, Sage Run, and Franklin. The Valley of Oil Creek, within a length of twenty miles, produced over $110,000,000 worth of oil, from an actual area of less than three square miles.

The Lower Oil Belt begins at Triangle City, Beaver Creek, Clarion County, and runs southwest twenty-one miles to St. Joe, in Butler County, and is the greatest producing area so far found (H. E. Wrigley, *op. cit.*). In 1866 rock with some oil was struck at Brady's Bend at a depth of 1,100 feet, giving rise to further investigation of the river above, which resulted in the discovery of a sand-rock of 57 feet thickness, at a depth of 960 feet, on the Alleghany River at Parker's Landing. A number of wells that had been supposed failures were afterward drilled to the proper depth, with great results.

The oil-bearing rock of Pennsylvania is a sand-rock, of which different strata are struck at different depths.

The operators speak of these as the first *sand*, second *sand*, and so on. After going through loose soil and a shale or slate-rock, the *first sand* is struck generally near the surface in the upper oil-regions (at a depth of 71 feet in the case of the first well sunk, the Drake well); 100 to 200 feet below this is the *second sand;* at 300 to 400 feet more the *third sand*, and then a *fourth* and *fifth* sand at intervals of about 150 feet. These sand-rocks are generally light-colored, and are separated by slate and other dark sand-rocks.

The heavy oil of Franklin comes from a sand-rock 260 feet deep, and from 50 to 80 feet in thickness. The lower sand-rocks are said to produce very bright, pure oils. Only 39.5 square miles of the 3,115 miles of the oil-region of Pennsylvania are actually productive.

The West Virginia oil-wells occur along an anticlinal extending from the borders of Southern Ohio through Wood, Wirt, and Ritchie

Counties, between thirty-five and forty miles. No oil is found in the horizontal rocks, but it occurs along the disturbed and broken, tilted strata on the edges of the line of uplift. This same belt runs north into Ohio, through Washington and Morgan Counties into Noble County. Volcano, White Oak, and Burning Springs are the principal points in West Virginia. The oil is found in subcarboniferous rocks, ascending to them from the underlying Devonian.

In Ohio there is another oil-belt, west of the above, beginning in Perry and Morgan Counties on the north, and running south through Athens into Meigs County; and in Cuyahoga and Trumbull Counties are oil-regions closely related to those of Western Pennsylvania. The "Mecca" oil, a valuable lubricating oil, occurs in the Mecca Oil Rocks (Berea grit and Bedford shales) of Trumbull County, Ohio. The total production of Ohio and West Virginia is not over 500 barrels daily (Wrigley).

The Kentucky oil-district is mainly in Barren and Cumberland Counties, with a small adjoining tract south of it in Overton County, Tennessee. A well in Cumberland County, 191 feet deep, produced 300 barrels daily. The abundant supply from Pennsylvania and the difficulty of transportation have prevented these regions from becoming well known.

Origin and Source of Petroleum.—At first it was held by many that petroleum was a result of distillation from the bituminous coals, which were found in its vicinity, and this belief was strengthened by the fact that some of the very bituminous coals, such as Cannel and Boghead coal, afforded large quantities of similar oils on being distilled; but, although this is very probably the source of a small amount of oil, yet the larger part of it is now believed to derive its origin from rocks lying below the coal-measures, since the oil-bearing rocks are mostly older than the carboniferous formations.

Some investigators have ascribed a vegetable origin to petroleum, but most authorities agree in attributing it to animal as well as vegetable agencies. Shales are the most common oil-bearing rocks, and in their formation the organic materials would be finely divided and protected from oxidation. The oil-bearing shales commonly show few vegetable remains, and Dana observes that the absence of distinct fossil animal and vegetable remains points to an abundance of delicate water-plants or infusorial or microscopic vegetable life as the source of the organic material contained in them. Limestones, on the other hand, are frequently full of animal fossil remains, showing an animal origin for the oil in them, although it is by no means agreed that the petroleum in certain limestones was derived from organic remains in the limestones and not from other strata below them. In whatever shape the finely-divided material was originally present, it would be finely diffused through the mud, and protected from atmospheric agencies, and subsequently the hydrocarbons would be formed from them, probably at but a slight elevation of temperature, produced by the same agencies which have caused elevations in the temperature of the interior of the earth's crust at various points.

Dana has further pointed out how petroleum might be formed by the reactions of the organic vegetable remains alone, the abstraction of some carbon and oxygen, as carbonic acid, accounting for the formation of the lighter oils; while the escape of some marsh-gas from less confined material would account for the heavier oils.

Newberry attributes the disagreeable smell of some limestone-oil to its animal origin, and Dufrenoy alludes to the abundance of fish fossils as a proof that the oil of various European districts was derived from animal remains.

As regards the circumstances favoring the accumulation of petroleum, it appears that there should be a shale or other fine-grained rock forming to protect the organic matter during its deposition, a porous stratum above to be penetrated by the hydrocarbons resulting from the decomposition of the organic matter, and finally another shale or slate above, to prevent the further escape of the volatile products. If the sand-rock which usually forms the porous stratum is filled with fissures, large quantities of oil may collect in these.

The petroleum of Enniskillen, Canada, is ascribed by Hunt to the Corniferous limestone of the Lower Devonian. Many geologists ascribe the oil of Pennsylvania, West Virginia, Ohio, and the rest of this grand oil area, to the black shale or Genesee slate of the Middle Devonian. Dr. J. S. Newberry, in his "Report of the Geological Survey of Ohio," says of the Huron (black) shale of the Middle Devonian in Ohio, that it is bituminous, and contains sheets of asphalt or asphaltic coal. Oil and gas springs are associated with its outcrop, and there is reason to believe that it supplies the wells of Oil Creek, Pennsylvania. Hydrocarbons are the product of spontaneous distillation in the outcrops of the Huron shale in Ohio. It shows traces of marine vegetation, and represents the Gardeau shale of New York, with whatever there is in Ohio of the underlying Genesee slate. Its materials appear to have accumulated in a quiet water-basin, being marine and not terrestrial vegetation. It forms a vast repository of hydrocarbonaceous matter, yielding ten to twenty gallons of oil per ton by distillation.

A line of oil and gas springs marks its outcrop, from Central New York to Tennessee. Emanations of oil and gas occurring from Lower Silurian rocks at Collingwood, Canada, and on the Upper Cumberland River, Kentucky, are associated with similar deposits of black shale representing the Utica shale (Lower Silurian) of New York. The wells of Oil Creek penetrate strata immediately overlying the Huron shale, and the oil is obtained from fissured and porous sheets of sand stone of the Portage and Chemung groups, which lie just over the Huron and offer convenient reservoirs for the oil it furnishes. It is a well-known fact that wells sunk into the black shale yield no considerable quantity of oil, unless from strata resting upon it.

The foregoing statements, it will be seen, go to substantiate the theory upheld by Newberry, in common with other geologists, that the strata yielding much oil have only served to store the oil which comes from other strata below. T. S. Hunt holds that the petroleum of the limestone of Ontario, Canada, and other localities is largely the result of decomposition of the organic matters in these same rocks, and not of distillation from below. This view Newberry opposes on the following grounds: The Corniferous limestone, from his very extended observations, contains little hydrocarbons; oil and gas springs are rare where it underlies the surface; no considerable quantity of petroleum has been derived from wells in the Corniferous, Niagara, or any other limestone; even at Chicago there are no paying wells. Borings have been unsuccessful in Ohio wherever the Corniferous is the surface rock; and, further, there is no Corniferous limestone where Hunt cites it in Kentucky. There is positive proof that part of the oil comes from a lower horizon, and probably the Canada oil comes from underlying Silurian Collingwood shale. On Oil Creek are the argillaceous shales of the Waverley and Chemung strata, forming the sides and bottom of the valley, and below are several beds of sandstone, with the black shales of the Portage and Genesee still lower. In Ohio these favorable conditions are wanting; the sand-rocks of Oil Creek thin out and give place to fine, impervious, argillaceous shales; the strata become more homogeneous and free from crevices, and hence the oil cannot penetrate them so well. In Cuyahoga County, Ohio, the wells reach down through carboniferous rocks to the Huron shale, but there are no good wells, because the sandstone reservoirs are lacking, and only close-grained shales are present.

Hunt, on the other hand, holds that the petroleum of Southwest Ontario, and probably in other localities, is to be sought in the oliferous limestones of the Corniferous and Niagara formations, both of which abound in indigenous petroleum (*American Journal of Science*, III., ii., 369), which, in the case of the Ontario limestone, he shows cannot have come from overlying strata. He also mentions a well sunk at Terre Haute, Indiana, 1,900 feet deep, which yields two barrels of oil daily; and a second one, very near, which yields 25 barrels. This one is 1,625 feet deep, and passes through 700 feet of coal-measures, 700 feet of carboniferous limestone, with underlying sandstone and shales, 50 feet of Genesee slate (or its equivalent), and at a depth of 25 feet below this the oil-vein was met with in Corniferous limestone. A third well, a mile east, at a depth of 2,000 feet showed no oil.

The truth seems to be, that these limestones may contain a little petroleum indigenous to them, but they have not furnished the grand supplies of very productive regions. Before leaving this part of the subject, mention should be made of the gas which so generally accompanies the oil. It is often met with in the oil-regions when no oil is struck, producing "gas-wells;" and is also met with where no oil, or very little, is found, on the borders of the oil-districts. Many private residences and manufacturing establishments are heated and lighted by this gas; Fredonia, New York, has been lighted with it for years. The Newton gas-well, five miles south of Titusville, Pennsylvania, is 786 feet deep, and yielded 4,000,000 cubic feet per day, supplying light and fuel to a great number of dwellings and manufactories in Titusville. A rolling-mill near Pittsburg is run by gas brought from Butler County, a distance of about nineteen miles, and when it is not needed the gas is lighted, furnishing a jet of flame seventy feet high, which, with another jet from a neighboring mill, furnishes a grand spectacle at night.

This gas is the cause of spouting-wells. If a well is sunk into the top of a fissure containing oil and gas, the gas will first escape, and then the oil must be pumped out; but, if the well strikes in the oil, the pressure of the gas would first drive out the oil. If water also was present and the well struck the bottom of the fissure the heavier water would first escape, then the oil, and then the gas. Such a well, after standing a while would again yield oil on pumping, then perhaps water only, or water and oil, until it had had another rest. If the supply of gas is kept up by an open crevice, the well may continue to flow for some time. The pressure of neighboring water may also cause the oil to flow from a well. Generally the pumping-wells are pretty constant, although when a number of wells are bored near together they interfere with each other, and sometimes water poured down one well will appear in another, and this method has been pursued to bring rival well-owners to terms.

A few words may here be said about drilling wells and transporting the oil. The wells are drilled by means of drilling-tools like those used in sinking artesian wells, which are suspended by a cable, and operated by small steam-engines. The well is lined with wrought-iron tubing, screwed together in sections, and, to prevent water from flowing down the outside of the lining into the well, a water-packer is used, which is essentially a circular piece of leather with the edges cut and turned upward, so that the whole forms a cup about the tube, which is pressed tightly against the sides of the well by the weight of the column of water. It is much better than the old flaxseed bag. The oil is conveyed from the oil-district to the refineries and shipping-stations by means of wrought-iron pipes, two to four inches in diameter, which form a network throughout the entire country, and have an aggregate length of nearly 2,000 miles. One company carries the oil thirty-seven miles, in this way, from Butler County to the vicinity of Pittsburg.

Refining and Uses of Petroleum.—Crude petroleum contains gases and volatile liquids giving off at ordinary temperatures gases, which form explosive mixtures with air; heavy oils, which injure its burning properties, but are useful as furnishing lubricators and paraffine; tarry and carbonaceous matters; sulphur and other compounds, which give an offensive odor when burned. It is therefore refined by distillation, to separate the useful products in a pure state. The general features of the process will be best illustrated by a practical example, and for this purpose we have selected the well-known refinery of Charles Pratt & Co., at Greenpoint, Long Island, manufacturers of Pratt's Astral Oil. This establishment has a capacity of 15,000 barrels weekly.

The crude oil, coming mostly from Pennsylvania, with a specific gravity of 46 to 48° Beaumé, is run into horizontal cylindrical stills of wrought-iron, heated by anthracite fires. Eight of these stills have a capacity of 600 barrels each, and there are eight smaller ones. From these stills pipes lead to large worms, cooled by running water, and connected with a series of small tanks, so that the products from each still can be separately collected, and the successive portions that come from the still can be kept apart, according to their specific gravity.

At about 160° Fahr. (70° C.) the gases begin to come off abundantly, and these are conducted from the lower end of the worms to heat the steam-boilers. At about 225° Fahr. (107° C.) gasoline, having a specific gravity of 85° B., begins to run from the worm; after an hour and a half, at a temperature of 325° Fahr. (163° C.) naphtha begins to run, with a density of 74° B., and continues for about three hours; at 350–400° Fahr. (177–200° C.) benzine, with a density of 62° B., begins and runs about one hour. For the remainder of the heat, about thirty hours, illuminating oil is collected, with a density of 48–50° B., and ending with a temperature of 750° Fahr. (398 C.). The residuum, having a density of 20° B., is drawn off and shipped in barrels to the paraffine and lubricating oil-works. Steam is then run into the still for nearly two hours to remove the gas, the man-hole is opened, and the coke scraped off to be used for fuel.

The results of this operation are about as follows:

| | | |
|---|---|---|
| Gasoline | 3 | per cent. |
| Naphtha | 10 | " " |
| Benzine | 3 | " " |
| Illuminating oil | 75 | " " |
| Residuum | 4 | " " |
| Coke and loss | 5 | " " |
| Total | 100 | |

The residuum yields by subsequent treatment paraffine to the amount of about one per cent. of the crude petroleum.

The illuminating oil comes from the worm at a temperature of about 80° Fahr. (49° C.) and is pumped from the receiving-tank into the agitator, an immense cylindrical tank of boiler-iron, holding 1,800 barrels (a smaller one holds 500), where it is cooled (if necessary) to 60° Fahr. by water run in at the top by sprinkling from a hose, and drawn off below. Forty-four gallons of strong commercial sulphuric acid being added for every 100 barrels of oil, the mixture is agitated by air pumped in through a pipe leading down through the oil to the bottom. This is done by an engine, and produces a very thorough mixture, during which the temperature rises, and when it reaches 70° Fahr. (21° C.) the operation is ended. Water is then played upon the top for about three hours, when caustic-soda lye of 20° B. is added, in the proportion of 500 gallons to 1,800 barrels of oil, thoroughly agitated with the oil, and then drawn off at the bottom after settling. The sulphuric acid purifies the oil partly by combining with, partly by breaking up, the injurious compounds, and the soda is added to neutralize the acid. Finally, the oil is again washed with water and drawn off into bleaching-pans, of which one has a capacity of 2,000 barrels, and two others of 750 each. Here the oil is left under a roof and exposed to diffused daylight four or five hours, to improve its color, and is then removed to the storage-tanks. It is possible to expose the oil too long in the bleachers, injuring its color. It is a curious fact, noticed in several refineries, that the oil, after removal to the agitator and before treatment with the acid, sometimes gives off spontaneously inflammable gas, which has been known to take fire during the cooling with water.

The gasolene is used for making gas. The naphtha and benzine destined for the market are kept separate, but sometimes they are further treated at the refinery, and are then run together, and sent to the naphtha-works with a density of 68° to 70° B. Here they are treated in iron stills of 200 to 600 barrels capacity, heated by coal. The vapors are condensed in a series of three worms, and the operation is so managed that the various products are obtained of the required density. These products are gasolene, of 90° (sometimes 97°), 88°, and 86° B.; naphtha, of 76° and 71°; benzine, of 65° and 62°. Most of the benzine shipped is of the latter density. The barrels used for shipping all of these products are coated inside with glue.

The residuum is either "cracked" in special stills (a process of which we shall have more to say hereafter) or it is sold to be worked up for lubricating oils and paraffine.

Mr. Joshua Merrill, manufacturing chemist of the Downer Kerosene Oil Company, has made several very important discoveries in the treatment of petroleum, and a short account of them has been given in a "Memoir on Petroleum Products," communicated to the Society of Arts, Massachusetts Institute of Technology, by S. D. Hayes, March 14, 1872, from which some facts are here selected:

Neutral lubricating oil, free from offensive odors and tastes, was partly the result of an accident. The condenser of a still heated by direct fire and charged with 900 gallons of mixed heavy and light oils, became partially closed, and the pressure caused leakage at the bottom of the still. The fire was very gradually drawn, after 250 gallons of light oil had passed off. The next day the oil in the still was found to be light-yellow, nearly odorless, neutral, and dense; the light, odorous hydrocarbons having been removed, at this low temperature, without decomposing either the distillate or the oil in the still. Further experiments perfected the process, which is greatly aided by the admission of steam from an open pipe into the body of the still during distillation.

Mineral sperm-oil was the result of experiments by Messrs. J. and R. S. Merrill on burning heavy lubricating oil and paraffine in lamps, especially constructed for the purpose. The light was very good, but the liquid was too thick to ascend into the wick. To obviate this the oil was subjected to a partially destructive distillation, "cracking" it enough to render it mobile, but not volatile.

The manner in which the crude petroleum is treated to obtain these various products is briefly outlined here from Prof. Hayes's sketch: The crude oil is heated by steam in upright, wrought-iron cylinders, incased in wood, of 12,000 gallons capacity. About 15 per cent. of distillate passes off and is condensed in pipes surrounded by water, yielding gasolene and A, B, and C naphthas, which are separately collected. From the gasolene rhigolene can be obtained by a second distillation with steam-heat, condensing the first portions of the distillate by ice and salt; ten per cent. is obtained from the gasolene. The steamed oil is pumped from the naphtha-stills into small stills, holding 1,000 gallons each, and heated by direct fires. Only carbon remains in these stills, some uncondensable gas escapes, and the other products are: No. 1, crude illuminating oil; No. 2, intermediate oils; No. 3, crude lubricating oil. Each of these is redistilled in the same sort of still. No. 1 is agitated with sulphuric acid, then with caustic soda, and distilled, yielding 80 per cent. of its volume of finished kerosene (refined illuminating oil) and mineral sperm-oil, and nearly 20 per cent. of denser oil. No. 2 is at once redistilled, yielding chiefly crude lubricating oil. No. 3 is agitated with sulphuric acid and then distilled with caustic soda in the still, yielding mainly dense paraffine-oil. This is kept in wooden barrels in ice-houses from seven to ten days, and deposits crystalline paraffine, which is pressed in strong cloth bags, one above another, with sheet-iron between, and yields crude paraffine-wax and heavy oil. The paraffine is repeatedly recrystallized from solution in naphtha and pressed, until it is white and pure enough for sale. The heavy oil is heated in stills by direct fires, slowly increased, but kept as low as possible, and generally with the admission of steam, until 20 to 30 per cent. has passed over. The residue is ready for sale, having only a slight odor like that of fat-oils, while the hydrocarbons that are condensed after passing over have a very offensive odor. The very last distillates from all of the destructive distillations are called "cokings," and are distilled by themselves, yielding mainly crude lubricating oil. The carbon separated in the stills contains some caustic soda, which can be obtained as carbonate by burning the carbon and lixiviating the ashes. The sulphuric acid used in agitating the oils is known as "sludge," and is sometimes sold to the makers of superphosphate of lime, although it has been occasionally successfully reconverted into oil of vitriol. The following list includes the commercial products which have been made from petroleum, being those already mentioned, with the exception of cymogene, which is distilled from gasolene, and condensed by a pump:

1. *Cymogene,* specific gravity 110° Beaumé; boils at 32° F. (0° C.); used in ice-machines. 2. *Rhigolene,* sp. gr. 100° B.; boils at 65° F. (18.3° C.); extremely volatile, producing by its rapid evaporation a temperature of —19° F.; used as a local anæsthetic. 3. *Gasolene,* sp. gr. 97°, 90°, 88°, and 86° B., as required by the market. The very light gasolene is ordered in small quantities, probably for ice-machines. The others are used in gas-machines, for which they are admirably adapted, and for various exceedingly dangerous lamps and stoves designed for their combustion. 4. *Naphtha,* sp. g. 70° to 76° B.; boils at 180° F. (27 C.), when of 70° gravity; used in manufacture of oil-cloths, cleansing, as a solvent for paraffine, etc.; sometimes fraudulently mixed with the higher-priced illuminating oils, or with crude petroleum, to be again sold to the refiner; also sold, under various names, as a burning-fluid, notwithstanding the certain danger attending its use. 5. *Benzine,* sp. gr. 65° to 62° B.; the boiling-point for 65° B. is 300° F. (149° C.); used in making paints and varnishes. 9. *Illuminating oil* (*kerosene*), sp. gr. 45° to 50° B.; boiling-point for 45° B. is 350° F. (177° C.). "Astral" oil and "mineral sperm" are particularly safe varieties, freed with care from explosive compounds. 7. *Lubricating oil.* "Neutral" lubricating oil has a specific gravity of 29° B., and boils at 575° F. (301.5° C.). 8. *Paraffine,* sp. gr. 0.87°; fusing-point for commercial paraffine about 110° to 150° F. (43.3° to 65° C.), according to its purity; boiling-point about 698° F. (370° C.); used for making water-proof fabrics, candles, lubricators, matches, chewing-gum, etc.

The refined illuminating oil should be free from more volatile compounds, which cause it to give off vapors that explode when mixed with air and ignited. Dr. White, President of the New Orleans Board of Health, found that, on adding to oil which "flashed" at 113° F. one per cent. of naphtha, the mixture flashed at 103°; with two per cent. at 92°; with five per cent. at 83°; with 20 per cent. the oil itself burned at 50° ("Report on Petroleum to New York Board of Health," Dr. C. F. Chandler, 1871). Dr. Chandler has found that the temperature of the oil in an ordinary glass oil-lamp ranges from 76 to 98° F., and in a metal lamp from 76° to 129° F., the lower limits being for rooms heated between 73° and 74° F., and the higher for a temperature of 90° to 92°. It is, therefore, evident that an oil giving off explosive gases at less than 100° F. must be dangerous, and even at 110° F. an accident might occur, but only in exceptional circumstances.

The oils must, therefore, stand a certain test, called the "flashing test," which consists in heating them, preferably, in a thin metal or glass cup which holds the oil, and is itself placed in another vessel full of cold water, which is gradually heated by a small spirit-lamp. The bulb of a thermometer is kept well immersed beneath the surface of the oil, draughts are to be avoided, and the heat very slowly raised. From time to time, as the flashing-point is approached, the temperature is noted, and a very small flame, as a gas-jet issuing from a glass tube drawn to a fine point, is quickly passed across its surface, taking care not to touch the oil. A faint blue flame will flash across the oil when it reaches a temperature at which explosive gases are given off. Although it is generally agreed that the temperature should be very gradually raised, fifteen minutes being allowed for a test, yet Calvert (*Chemical News*, May, 1870) states that an oil which flashed at 90° F., after fifteen minutes, showed a flashing-point of 101°, when thirty minutes were consumed in making the test. Oil of 100° is *not safe absolutely*. There is another test called the burning-test, the point at which an oil will take fire and burn; it is from 10° to 50° F. above the flashing-test (Chandler), and is of little value in determining the safety of an oil, because, as already shown, the addition of one per cent. of naphtha will lower the flashing-test 10° in a good oil, while it would not materially affect the burning-point. From the directions already given for testing oil any one can readily make the test, and in view of the large number of unsafe oils sold it is very important that such tests should be made before using an oil not known to be safe.

The subject of refining petroleum may be dismissed with a few words more about "cracking" oils. It is the object of the refiner to make as much illuminating oil as possible, and to do this advantage is taken of the fact that, when the vapors of heavy oils are heated above their boiling-points, carbon is deposited, and the condensed hydrocarbons resulting have a less specific gravity. This decomposition is technically called "cracking," and it was observed long ago that in distilling the heavier oils lighter hydrocarbons were obtained during the first stages of the operation, even when not wanted. Cracking can be accomplished by distilling the oils under pressure, or, as is the case in the very large stills now employed, by allowing the vapors of the heavier hydrocarbons, on condensing, to flow down again upon the now hotter oil in the still, whereby they are cracked, depositing carbon. By carefully adapting the heat to the changing character of the oil, the yield of illuminating oil can be increased, but a residuum is always left in the large stills to be afterward treated in smaller ones.

S. D. Hayes states that this operation can be reversed, and from two to ten per cent. of a heavy oil obtained from the lightest and cheapest gasolene or petroleum naphtha. This change he observed in an apparatus constructed by Mr. Z. A. Willard, for generating gases and hydrocarbon vapors for metallurgical purposes. It consisted essentially of upright wrought-iron cylinders, half-full of the naphtha, through which steam at the ordinary working temperature and pressure passed, vaporizing the naphtha, and maintaining a pressure of about fifty pounds to the inch. The steam and naphtha vapors were thus kept above the liquid at a temperature much above the boiling-point of naphtha, but never as high as 300° Fahr., and the decompositions appeared to occur rather in the vapors than in the liquid. The heavy oil drawn off below had a dark yellowish-brown color, was nearly odorless after a few days' exposure to the air, had a specific gravity of about 34° Beaumé, and boiled above 400° Fahr. By redistilling, it was broken up into lighter and heavier liquid hydrocarbons, paraffine, and separated carbon (*American Journal of Science*, III., ii., 184).

Petroleum as a Fuel and Gas-Producer.—The use of gasolene in gas-machines is well known, and sometimes naphtha has been used to enrich coal-gas, by decomposing its vapor at a cherry-red heat, so as to produce a gas rich in heavy hydrocarbons, which is mixed with the coal-gas. Crude petroleum has also been conducted continuously into red-hot cast-iron retorts, whereby it is decomposed and rich gas formed. The Lowe process, now making daily 120,000 cubic feet of gas, of 19.5 candle-power, for a five-foot burner, at Utica, New York, is very successful. It consists essentially in forcing steam through a generator partly full of anthracite coal, brought to intense ignition; the steam is decomposed, and the resulting hydrogen meets crude petroleum that trickles down through the top of the generator; the petroleum is carried in vapor with the hydrogen into a "superheater" filled with loose fire-bricks, previously intensely heated by the gases from the generator. Here the hydrogen and hydrocarbons react upon each other, producing a permanent gas, which is purified as usual. The resulting gas is of uniform quality, very pure, and the saving in labor and materials is about 35 per cent. over coal-gas (*Scientific American*, January 8, 1876).

As regards the use of petroleum for fuel, it has always been found difficult to secure the complete combustion of the oil, so as to avoid smoke; the complicated nature of the contrivances devised for its use has also worked against its introduction as a fuel; but a furnace for reheating and rolling scrap-iron into boiler-plate has been invented by C. J. Eames, and is worked in Jersey City, which deserves mention. Prof. H. Wurtz (*American Chemist*, September, 1875) has described it at length. A current of steam heated to incandescence, meeting crude petroleum as it drips slowly over cast-iron shelves, takes up all the oil and carries it to a chamber where it meets an air-blast and passes on to the combustion-chamber. This is a cellular tier of fire-bricks occupying the space over the bridge-wall of an ordinary furnace. Here the combustion begins, and thence the flames pass into the furnace, heating the six piles of iron, of 500 pounds each, which form a charge. Eight tons of boiler-plate can be worked off in ten hours with 300 gallons of crude petroleum, to which should be added 500 pounds of coal for generating and heating the steam. Petroleum is also used as a source of power in hydrocarbon engines (G. B. Brayton's), its vapor being mixed with air and ignited.

PRODUCTION AND VALUE OF PETROLEUM AND ITS PRODUCTS.—When the first abundant supplies of petroleum were obtained, the demand for it as an illuminator was small, and it could be bought at the wells for ten cents a barrel, or was even allowed to run to waste (Wrigley), but as the consumption increased the price rose steadily, reaching, in 1864, $13.75 per barrel. The average prices per barrel at Titusville are given below, taken from *Stowell's Petroleum Reporter*, Pittsburg:

| | | | |
|---|---|---|---|
| 1864 | $7 62 | 1870 | $3 74 |
| 1865 | 6 18 | 1871 | 4 50 |
| 1866 | 3 78 | 1872 | 3 84 |
| 1867 | 2 54 | 1873 | 1 84 |
| 1868 | 3 95 | 1874 | 1 29 |
| 1869 | 5 48 | 1875 | 1 48 |

The production of the Pennsylvania oil-region, from 1859 to 1874, according to Wrigley, has been as follows:

| | | | | | |
|---|---|---|---|---|---|
| 1859 | 3,200 | barrels. | 1867 | 3,347,306 | barrels. |
| 1860 | 650,000 | " | 1868 | 3,715,741 | " |
| 1861 | 2,113,600 | " | 1869 | 4,215,000 | " |
| 1862 | 3,056,606 | " | 1870 | 5,659,000 | " |
| 1863 | 2,611,359 | " | 1871 | 5,795,000 | " |
| 1864 | 2,116,182 | " | 1872 | 6,539,103 | " |
| 1865 | 3,497,712 | " | 1873 | 9,879,303 | " |
| 1866 | 3,597,527 | " | 1874 | 10,910,303 | " |

The yield for 1859 is put at about 2,000 barrels by Mr. S. H. Stowell, who has also kindly furnished the following statistics:

*Total Yield of the United States in* 1875.

| | | |
|---|---|---|
| Pennsylvania | 8,787,506 | bbls., of 42 galls. |
| Western Virginia (approximated) | 182,000 | " " " |
| All other sources, " | 17,150 | " " " |
| Total | 8,986,656 | " " " |

The total value of the crude oils at the wells, up to the end of 1874, is given by Wrigley as $235,475,120, with an additional value for the refining of 75 per cent. of the whole, at $2 per barrel, of over $100,000,000. The stock of crude oil on hand at the wells, in December, 1875, was 3,550,207 barrels. The total export from the United States during 1875 was: Crude petroleum, 378,532 barrels (of 40 gallons each); refined, 5,086,785; naphtha, 344,978. The average price of these in New York has been, per gallon:

| | Crude, in Bulk. | Refined, in Barrels. | Naphtha, in Barrels. |
|---|---|---|---|
| 1875.......... | 6.59 cents. | 12.99 cents. | 9.67 cents. |
| 1874.......... | 5.86 " | 13.09 " | 8.85 " |
| 1873.......... | 7.62 " | 18.21 " | 11.07 " |
| 1872.......... | 12.80 " | 23.75 " | 14.81 " |

Estimating the freight at $2.50 per barrel to the sea-board, and including the cost of refining and handling, Wrigley puts the total value of petroleum exported to foreign parts from Pennsylvania, since the beginning of the industry, at a minimum of $260,000,000.

In 1874 nearly 600 wells were drilled, producing an average of 50 barrels each; in 1875, about the same number, with an average of less than 25 barrels; and there were 3,125 producing-wells in Pennsylvania, January 1, 1876 (Stowell).

According to the rules of the New York Produce Exchange, crude petroleum shall be understood to be pure, natural oil, neither steamed nor treated, and free from water, sediment, or any adulteration, and of the gravity of 40° to 47° Beaumé. An allowance of one-half of one per cent. for every quarter of a degree above 47° gravity shall be made to the buyer. Refined petroleum shall be standard white or better, with a fire-test of 110° Fahr. or upward. Settlements of contracts shall be as follows: Barreled oil or naphtha, on a basis of forty-six gallons per barrel; refined oil, in bulk, forty-five gallons; crude oil, in bulk, forty gallons.

Dr. Chandler states that the average cost per hour of light equal to eight candles is as follows—the gas being sixteen-candle power, with a five-foot burner, the standard kerosene flashing at 115° Fahr., and the sperm-candles burning each 120 grains per hour:

| | | |
|---|---|---|
| From sperm-candles, at 42 cents per pound...................... | 5.76 | cents. |
| Gas, at $3 per 1,000 feet.................................. | 0.75 | " |
| Mineral sperm-oil, in German student-lamp, at 75 cents per gallon.. | 0.57 | " |
| " " in Merrill's lamp............................ | 0.48 | " |
| Astral oil, in flat-wick lamp, at 50 cents per gallon............... | 0.46 | " |
| " " in German student-lamp.......................... | 0.44 | " |
| " " in Merrill's lamp .......................... | 0.34 | " |
| Standard kerosene, in flat-wick lamp, at 40 cents per gallon........ | 0.33 | " |
| " " in German student-lamp ..................... | 0.31 | " |
| " " in Merrill's lamp .................... | 0.28 | " |

# LESSONS IN ELECTRICITY.[1]

## HOLIDAY LECTURES AT THE ROYAL INSTITUTION.

By Prof. TYNDALL, F. R. S.

### III.

SECTION 13. *Electric Induction.*—We have now to apply the theory of electric fluids to the important subject of electric *induction.*

It was noticed by early observers that *contact* was not necessary to electrical excitement. Otto von Guericke, as we have already seen, found that a body brought near his sulphur globe became electrical. By bringing his excited glass tube near one end of a conductor, Stephen Gray attracted light bodies at the other end. He also obtained attraction through the human body. From the human body, also, Du Fay, to his astonishment, obtained a spark. Canton, in 1753, suspended pith-balls by thread, and, holding an excited glass tube at a considerable distance, caused them to diverge. On removing the tube the balls fell together, no permanent charge being imparted to them. Such phenomena were further studied and developed by Wilcke and Æpinus, Coulomb and Poisson.

These and all similar results are embraced by the law that, when an electrified body is brought near an unelectrified one, the neutral fluid of the latter is decomposed, one of its constituents being attracted, the other repelled. When the electrified body is withdrawn, the separated electricities flow again together and render the body unelectric.

This decomposition of the neutral fluid by the mere presence of an electrified body is called *induction.* It is also called electrification by *influence.*

If, while it is under the influence of the electrified body, the body influenced be touched, the free electricity (which is always of the same kind as that of the influencing body) passes away, the opposite electricity being held captive.

On removing the electrified body the captive electricity is set free, the conductor being charged with electricity opposite in kind to that of the body which electrified it.

You cannot do better here than repeat Stephen Gray's experiment. Support a small plank upon a warm tumbler, and bring under one of its ends and near it scraps of light paper or of gold-leaf. Excite your glass tube vigorously, and bring it over the other end of the plank, without touching it. The ends may be six or eight feet apart; the light bodies will be attracted. The experiment is easily made, and you are not to rest satisfied till you can make it with ease and certainty.

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[1] A course of six lectures, with simple experiments in frictional electricity, before juvenile audiences during the Christmas holidays.

This is a fit place to say that you must keep a close eye upon the tumblers you employ for insulation. Some of them, made of common glass, are hardly to be accounted insulators at all. We shall prove this.

Our mastery over this subject of induction must be complete, for it underlies all our subsequent inquiries. Without reference to it nothing is to be explained; possessed of it you will enjoy, not only a wonderful power of explanation, but of prediction. We will attack it, therefore, with the determination to exhaust it.

And here a slight addition must be made to our apparatus. We must be in a condition to take samples of electricity, and to convey them, with the view of testing them, from place to place. For this purpose the little "carrier," shown in Fig. 10, will be found convenient. *T* is a bit of tin-foil, two or three inches square. A straw stem is stuck on to it by sealing-wax, the lower end of the stem being covered by sealing-wax. To make the insulation sure, the part between *R* and *S'* is wholly of sealing-wax. You can have stems of ebonite, which are stronger, for a few pence; but you can have this one for a fraction of a penny. The end *R'* is to be held in the hand; the electrified body is to be touched by *T*, and the electricity conveyed to an electroscope to be tested.

FIG. 10.

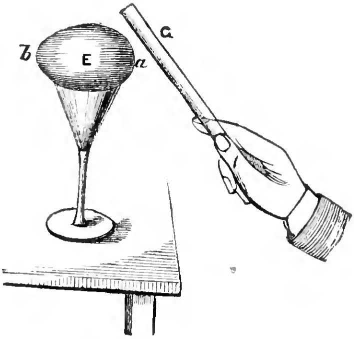

FIG. 11.

Touch your rubbed glass rod with *T*, and then touch your electroscope: the leaves diverge with positive electricity. Touch your rubbed gutta-percha or sealing-wax with *T*, and then touch your electroscope: the leaves diverge with negative electricity. If the electricity of any body augment the divergence produced by the glass, the electricity of that body is positive. If it augment the divergence produced by the gutta-percha, the electricity is negative. And now we are ready for further work.

Place an egg, *E*, Fig. 11, on its side upon a dry wineglass; bring your excited glass tube, *G*, within an inch or so of the end of the egg. What is the condition of the egg? Its electricity is decomposed; the negative covering the end *a* adjacent to the tube, the positive covering the other end *b*. Remove the glass tube: what occurs? The two electricities flow together and neutrality is restored. Prove this neutrality. Neither a carrier touching the egg, nor the egg itself, has any power to affect your electroscope, or to attract a lath balanced in the manner already described.

Again, bring the excited tube near the egg. Touch its distant part *b* with your carrier. The carrier now attracts the straw or the balanced lath. It also causes the leaves of your electroscope to diverge. What is the *quality* of the electricity? It repels and is repelled by rubbed glass; the electricity at *b* is, therefore, positive. Discharge the carrier by touching it, and bring it into contact with the end *a* of the egg nearest to the glass tube. The electricity you take away repels and is repelled by gutta-percha. It is, therefore, negative. Test the quality, also, by the electroscope.

While the tube *G* is near the egg touch the end *b* with your finger; now try to charge the carrier by touching *b:* you cannot do so—the positive electricity has disappeared. Has the negative disappeared also. No. Remove the glass tube, and once more touch the egg at *b* with the carrier. It is charged, not with positive, but with negative electricity. Clearly understand this experiment. The neutral electricity of the egg is first decomposed into negative and positive; the former attracted, the latter repelled by the excited glass. The repelled electricity is free to escape, and it has escaped on your touching the egg with your finger. But the attracted electricity cannot escape as long as the influencing tube is held near. On removing the tube which holds the negative fluid in bondage, that fluid immediately diffuses itself over the whole egg. An apple, or a turnip, will answer for these experiments at least as well as an egg.

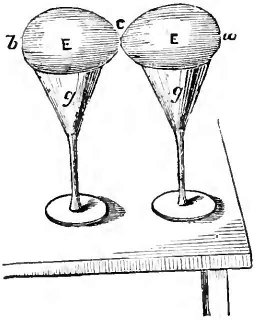

Fig. 12.

Discharge the egg by touching it. Reëxcite the glass tube and bring it again near. Touch the egg with a wire or with your finger at *a*. Is it the negative at *a*, into which you plunge your finger, that escapes? No such thing. The free positive fluid passes through the negative, and through your finger to the earth. Prove this, by removing first your finger and then the glass tube. The egg is charged negatively.

Again: place two eggs, *E E*, Fig. 12, lengthwise on two dry wineglasses, *g g*, and cause two of their ends to touch each other, as at *C*. Bring your rubbed glass rod near the end *a*, and while it is there separate the eggs by moving one glass away from the other. Withdraw the rod and test both eggs: *a* is negative, *b* is positive. The two charges neutralize each other in the electroscope. Again: bring the eggs together and restore the rubbed tube to its place near *a*. Touch *a* and then separate the eggs. Remove the glass rod and test the eggs: *a* is negative, *b* is neutral. Its electricity has escaped through the finger, though placed at *a*.

Push your experiments still farther, and, instead of bringing the eggs, *T T′*, Fig. 13, together, place them six feet or so apart, and let a light chain, *C*, or wire stretch from one to the other. Two brass balls or wooden balls covered with tin-foil, and supported by tall drinking-glasses, *G G′*, will be better than the eggs for this experiment, for they will bear better the strain of the chain; but you can make the experiment with the eggs, or very readily with two apples or two turnips. For the present we will suppose the straw-index *I I′* not to be there. Rub your glass tube *R*, and bring it near one of the balls; test both: the near one, *T′*, is negative, the distant one, *T*, positive. Touch the near one, the positive electricity, which had been driven along the chain to the remotest part of the system, returns along the chain, passes through the negative which is held captive by the tube, and escapes to the earth. When the tube is removed, negative electricity overspreads both chain and balls.

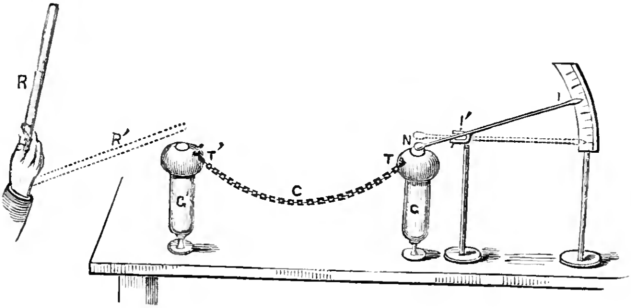

FIG. 13.

In Fig. 6 you made the acquaintance of the plate *N*, and the straw-index $I\ I'$, shown in Fig. 13. By its means you immediately see both the effect of the first induction and the consequence of touching any part of the system with the finger. The plate $N$ rests over the ball or turnip $T$, the position of the straw-index being that shown by the dots. Bring the rubbed tube near $T'$: the end $N$ of the index immediately descends and the other end rises along the graduated scale. Remove the glass rod; the index $I\ I'$ immediately falls. Practise this approach and withdrawal, and observe how promptly the index declares the induction and recomposition of the fluids.

While the tube is near $T$, and the end $N$ of the index is attracted, let $T''$ be touched by the finger. The end $N$ is immediately liberated, for the electricity which pulled it down escapes along the chain and through the finger to the earth. Now remove your excited tube. The captive negative electricity diffuses itself over both balls, and the index is again attracted.

Instead of the chain you may interpose between the balls one hundred feet of wire supported by silk loops. This is done in Fig. 14, which shows the wire $w$ supported by the silk strings $S\ S\ S$, and where, for the ball or turnip, the cylinder $C$, on a glass support $G$, is substituted. Every approach and withdrawal of the rubbed glass tube $R$ is followed obediently by the corresponding motion of the index.

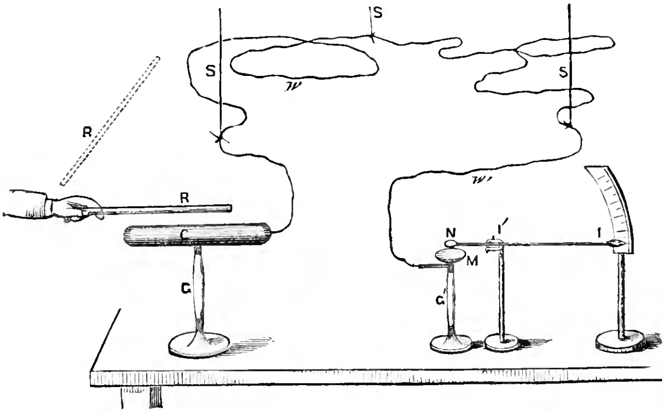

Fig. 14.

Or, substituting a carrot, a cucumber, or other elongated conductor for the ball $T'$, Fig. 12, you cause your rubbed glass tube to act upon a greater extent of surface. You thus decompose more electricity and produce a greater attraction.

Repeat here an experiment, first made by a great electrician named Æpinus. I wish you to make these grand old experiments. Support an elongated metal conductor, or one formed of wood coated with tin-foil—even a carrot, cucumber, or parsnip, so that it will be insulated, will answer. Let a small weight suspended from a silk string rest on one end of the conductor, and hold your rubbed glass rod near the other end. You can predict beforehand what will occur when you remove the weight. It carries away with it electricity, which repels rubbed glass, and which attracts your balanced lath.

Stand on an insulating stool: make one, if necessary, by placing a board on four warm tumblers. Present the knuckles of your right hand to the end of the balanced lath, and stretch forth your left arm. There is no attraction. But let a friend or an assistant bring the rubbed glass tube over the left arm; the lath immediately follows the right hand.

While matters continue thus, touch the lath, which I suppose to be uninsulated; the "attractive virtue," as it was called by Gray, disappears. After this, as long as the excited tube is held over the arm there is no attraction. But when the tube is removed the attractive power of the hand is restored. Here, you will at once comprehend, the first attraction was by positive electricity driven to the right hand from the left, and the second attraction by negative electricity, liberated by the removal of the glass rod.

Stand on an insulating stool, and place your right hand on the electroscope: there is no action. Stretch forth the left arm and permit an assistant alternately to bring near, and to withdraw, an excited glass tube. The gold-leaves open and collapse in similar alternation. At every approach, positive electricity is driven over the gold-leaves; at every withdrawal, the equilibrium is restored.

I will now ask you to charge your Dutch gold electroscope positively by rubbed gutta-percha, and to charge it negatively by rubbed glass. A moment's reflection will enable you to do it. You bring your excited body near: the same electricity as that of the excited body is driven over the leaves, and they diverge by repulsion. Touch the electroscope, the leaves collapse. Withdraw your finger, and withdraw afterward the excited body: the leaves then diverge with the opposite electricity.

The simplest way of testing the quality of electricity is to charge the electroscope with electricity of a known kind. If, on the *approach* of the body to be tested, the leaves diverge still wider, the leaves and the body are similarly electrified. The reason is obvious.

The wealth of knowledge, and of interest, which these experiments involve, may be placed within any boy's reach by the wise expenditure of half a crown.

Once firmly possessed of the principle of induction and versed in its application, the difficulties of our subject will melt away before us. In fact, our subsequent work will consist mainly in unraveling phenomena by the aid of this principle.

Without a knowledge of this principle we could render no account of the attraction of neutral bodies by our excited tubes. In reality, the attracted bodies are *not* neutral: they are first electrified by influence, and it is because they are thus electrified that they are attracted.

This is the place to stamp upon your mind the following considerations: Neutral bodies, as just stated, are attracted, because they are really converted into electrified bodies by induction. Suppose a body to be feebly electrified positively, and that you bring your rubbed glass-rod to bear upon the body. You clearly see that the induced negative electricity may be strong enough to mask and overcome the weak positive charge possessed by the body. We should thus have two bodies electrified alike, attracting each other. This is the danger against which I promised to warn you in Section 10, where the test of attraction was rejected.

We will now apply the principle to explain a very beautiful invention, made known by the celebrated Volta in 1775.

SEC. 14. *The Electrophorus.*—Cut a circle, T (Fig. 15), six inches in diameter, out of sheet-zinc, or out of common tin. Heat it at its centre by the flame of a spirit-lamp or of a candle. Attach to it there a stick of sealing-wax, H, which, when the metal cools, is to serve as an insulating handle. You have now the lid of the electrophorus. A resinous surface, or what is simpler a sheet of vulcanized India-rubber, P, or even of hot brown paper, will answer for the *plate* of the electrophorus.

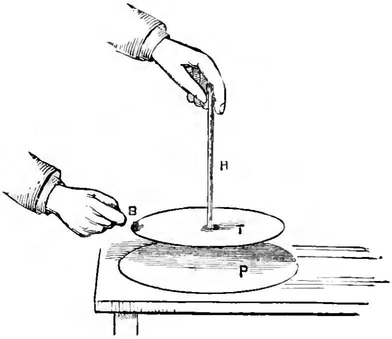

FIG. 15.

Rub your "plate" with flannel, or whisk it briskly with a fox's brush. It is thereby negatively electrified. Place the "lid" of your electrophorus on the excited surface: it touches it at a few points only. For the most part lid and plate are separated by a film of air.

The excited surface acts by induction across this film upon the lid, attracting its positive and repelling its negative electricity. You have in fact in the lid two layers of electricity, the lower one, which is "bound," positive; the upper one, which is "free," negative. Lift the lid: the electricities flow again together; neutrality is restored, and your lid fails to attract your balanced lath.

Once more place the lid upon the excited surface: touch it with the finger. What occurs? You ought to know. The free electricity, which is negative, will escape through your body to the earth, leaving the chained positive behind.

Now lift the lid by the handle: what is its condition? Again I say you ought to know. It is covered with free positive electricity. If it be presented to the lath it will strongly attract it; if it be presented to the knuckle it will yield a spark.

A smooth half-crown or penny will answer for this experiment. Stick to the coin an inch of sealing-wax as an insulating handle; bring it down upon the excited India-rubber: touch it, lift it, and present it to your lath. The lath may be six or eight feet long, three inches wide, and half an inch thick; the little electrophorus-lid, formed by the half-crown, will pull it round and round. The experiment is a very impressive one.

Scrutinize your instrument still further. Let the end of a thin wire rest upon the lid of your electrophorus, under a little weight if necessary, and connect the other end of the wire with the electroscope. As you lower the lid down toward the excited plate of the electrophorus, what must occur? The power of prevision now belongs to you and you must exercise it. The repelled electricity will flow over the leaves of the electroscope, causing them to diverge. Lift the lid, they collapse. Lower and raise the lid several times, and observe the corresponding rhythmic action of the electroscope-leaves.

A little knob of sealing-wax, *B*, coated with tin-foil; or indeed any knob with a conducting surface, stuck into the lid of the electrophorus, will enable you to obtain a better spark. The reason of this will immediately appear.

SEC. 15. *Action of Points and Flames.*—The course of exposition proceeds naturally from the electrophorus to the electrical machine. But before we take up the machine we must make our minds clear regarding the manner in which electricity diffuses itself over conductors, and more especially over elongated and pointed conductors.

Rub your glass tube and draw it over an insulated sphere of metal —of wood covered with tin-foil, or indeed any other insulated spherical conductor. Repeat the process several times, so as to impart a good charge to the sphere. Touch the charged sphere with your carrier, and transfer the charge to the electroscope. Note the divergence of the leaves. Discharge the electroscope, and repeat the experiment, touching, however, some other point of the sphere. The electroscope shows the same amount of divergence. Even when the greatest exactness of the most practised experimenter is brought into play, the spherical conductor is found to be equally charged at all points of its surface. You may figure the electric fluid as a little ocean encompassing the sphere, and of the same depth everywhere.

But supposing the conductor, instead of being a sphere, to be a cube, an elongated cylinder, a cone, or a disk. The depth, or as it is sometimes called the *density* of the electricity, will not be everywhere the same. The corners of the cube will impart a stronger charge to your carrier than the sides. The end of the cylinder will impart a stronger charge than its middle. The edge of the disk will impart a stronger charge than its flat surface. The apex or point of the cone will impart a stronger charge than its curved surface or its base.

You can satisfy yourself of the truth of all this in a rough but certain way, by charging, after the sphere, a turnip cut into the form of a cube; or a cigar-box coated with tin-foil; a metal cylinder, or a wooden one coated with tin-foil; a disk of tin or of sheet-zinc; a carrot or parsnip with its natural shape improved so as to make it a sharp cone. You will find the charge imparted to the carrier by the sharp corners and points, to be greater than that communicated by gently-rounded or flat surfaces. The difference may not be great, but it will be distinct. Indeed, the egg laid on its side, as we have already used it in our experiments on induction, yields a stronger charge from its ends than from its middle.

Let me place before you an example of this distribution, taken from the excellent work on "Frictional Electricity," by Prof. Riess, of Berlin, who is probably the greatest living exponent of the subject. Two cones, Fig. 16, are placed together base to base. Calling the strength of the charge along the circular edge where the two bases join each other 100, the charge at the apex of the blunter cone is 133, and at the apex of the sharper one 202. The other numbers give the charges taken from the points where they are placed. Fig. 17, moreover, represents a cube with a cone placed upon it. The charge on the face of the cube being 1, the charges at the corners of the cube and at the apex of the cone are given by the other numbers; they are all far in excess of the electricity on the flat surface.

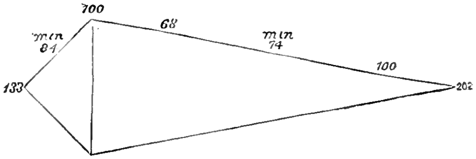

FIG. 16.

Riess found that he could deduce with great accuracy the *sharpness* of a point, from the charge which it imparted. He compared in this way the sharpness of various thorns with that of a fine English sewing-needle. The following is the result: Euphorbia-thorn was sharper than the needle; gooseberry-thorn of the same sharpness as the needle; while cactus, blackthorn, and rose, fell more and more behind the needle in sharpness. Calling, for example, the charge obtained from euphorbia 90, that obtained from the needle was 80, and from the rose only 53.

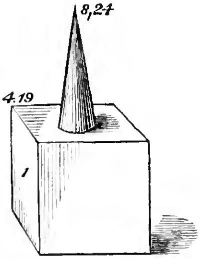

Fig. 17.

Considering that the electricity is self-repulsive, and that it heaps itself up upon a point in the manner here shown, you will have little difficulty in conceiving that, when the charge of a conductor carrying a point is sufficiently strong, the electricity will finally disperse itself by streaming from the point.

The following experiments are theoretically important: Attach a stick of sealing-wax to a small plate of tin, so that the stick may stand upright. Heat a needle and insert it into the top of the stick of wax; on this needle mount a carrot. You have thus an insulated conductor. Stick into your carrot at one of its ends a sewing-needle, and hold for an instant your rubbed glass rod in front of this needle without touching it. What occurs? The negative electricity of the carrot is discharged from the point against the glass rod. Remove the rod, test the carrot: it is positively electrified.

And now for another experiment, not so easily made, but still certain to succeed if you are careful. Excite your glass rod, turn your needle away from it, and bring the rod near the other end of the carrot. What occurs? The positive electricity is now repelled to the point, from which it will stream into the air. Remove the rod and test the carrot: it is negatively electrified.

Again, turn the point toward you, and place in front of it a plate of dry glass, wax, resin, shellac, paraffine, gutta-percha, or any other insulator. Pass your rubbed glass tube once downward or upward, the insulating plate being between the excited tube and the point. The point will discharge against the insulating plate, which on trial will be found negatively electrified. These experiments, I may say, were discussed, and differently interpreted by the two philosophers, during an important correspondence between Faraday and Prof. Riess.[1]

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[1] *Philosophical Magazine*," vol. xi., 1856.

SEC. 16. *The Electrical Machine.*—An electrical machine consists of two principal parts: the insulator which is excited by friction, and the "prime conductor."

The sulphur sphere of Otto von Guericke was, as already stated, the first electrical machine. The hand was the rubber, and indeed it long continued to be so. For the sulphur sphere Hauksbee and Winckler substituted globes of glass. Boze, of Wittenberg (1741), added the prime conductor, which was at first a tin tube supported by resin, or suspended by silk. Soon afterward Gordon substituted a glass cylinder for the globe. It was sometimes mounted vertically, sometimes horizontally. Gordon so intensified his discharges as to be able to kill small birds with them. In 1760 Planta introduced the plate machine now commonly in use.

Mr. Cottrell has constructed for these lessons the small cylinder machine shown in Fig. 18. The glass cylinder is about seven inches long and four inches in diameter; its cost is eighteen pence. Through the cylinder passes tightly, as an axis, a piece of lath, rendered secure by sealing-wax where it enters and quits the cylinder. *G* is a glass rod supporting the conductor *C*, which is a piece of lath coated with tinfoil. Into the lath is driven the series of pin-points, *P*, *P*. The rubber, *R*, is seen at the farther side of the cylinder, supported by the upright lath, *R'*, and caused to press against the glass. *S'* is a flap of silk. When the handle is turned sparks may be taken, or a Leyden-jar charged at the knob *C*. A plate machine is shown in Fig. 19. *P* is the plate; *R* and *R'*, two rubbers which clasp the plate. *A* and *A'* are rows of points presented by the conductor, *C*. *C C'* is an insulating rod of glass, intended to cut off the connection between the conductor and the handle of the machine.

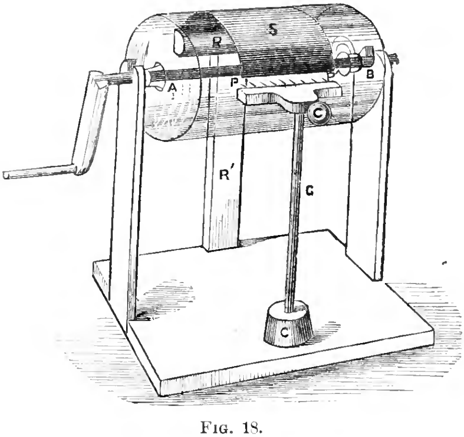

FIG. 18.

The prime conductor is thus charged: when the glass plate is turned, as it passes each rubber it is positively electrified. Facing the electrified glass is the row of points midway between the two rubbers. On these points the electrified glass acts by induction, attracting the negative and repelling the positive. In accordance with the principles already explained the negative electricity streams from the points against the excited glass, which passes on neutralized to the next rubber, where it is again excited. Thus the prime conductor is charged, not by the direct communication to it of positive electricity, but by depriving it of its negative.

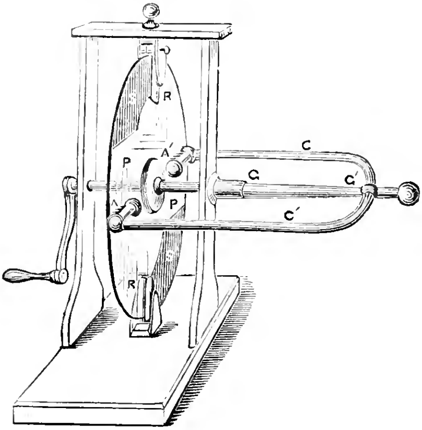

FIG. 19.

If, when the prime conductor is charged, you bring the knuckle near it, the electricity passes from the conductor to the knuckle in the form of a spark.

Take this spark while the machine is being turned, and then try the effect of presenting the finger-ends, instead of the knuckle, to the conductor. The spark falls exceedingly in brilliancy. Substitute for the finger-ends a needle-point, you fail to get a spark at all. To obtain a good spark the electricity upon the prime conductor must reach a sufficient density (or tension, as it is sometimes called). To secure this, no points from which the electricity can stream must exist on the conductor, or be presented to it. All parts of the conductor are therefore carefully rounded off, sharp points and edges being avoided.

It is usual to attach to the conductor an electroscope, consisting of an upright metal stem, *A C*, Fig. 20, to which a straw with a pith-ball, *B*, at its free end, is attached. The straw turns loosely upon a pivot at *C*. The electricity passing from the conductor is diffused over the whole electroscope, and the straw and stem, being both positively electrified, repel each other. The straw, being the movable body, flies away. The amount of the divergence is measured upon a graduated arc.

If no point exist on the conductor, a single turn of the handle of the machine suffices to cause the straw to stand out nearly at right angles to the stem. If, on the contrary, a point be attached to the conductor, you cannot produce a large divergence. The reason is, that the electricity, as fast as it is generated, is dispersed by the point. The same effect is observed when you present a point to the conductor. The conductor acts by induction upon the point, causing the negative electricity to stream from it against the conductor, which is thus neutralized almost as fast as it is charged. Flames and glowing embers act like points; they also rapidly discharge electricity.

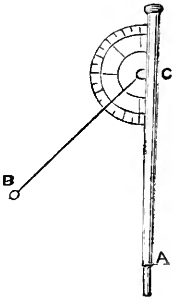

Fig. 20.

The electricity escaping from a point or flame into the air renders the air self-repulsive. The consequence is that, when the hand is placed over a point mounted on the prime conductor of a machine in good action, a cold blast is distinctly felt. Dr. Watson noticed this blast from a flame placed on an electrified conductor, while Wilson noticed the blast from a point. Jallabert and the Abbé Nollet also observed and described the influence of points and flames. The blast is called the "electric wind." Wilson moved bodies by its action; Faraday caused it to depress the surface of a liquid; Hamilton employed the *reaction* of the electric wind to make pointed wires rotate. The "wind" was also found to promote evaporation.

Hamilton's apparatus is called the "electric mill." Make one for yourself thus: Place two straws $S\,S$, $S'\,S'$, Fig. 21, about eight inches long, across each other at a right angle. Stick them together at their centres by a bit of sealing-wax. Pass a fine wire through each straw and bend it where it issues from the straw, so as to form a little pointed arm perpendicular to the straw, and from half an inch to three-quarters of an inch long. It is easy, by means of a bit of cork or sealing-wax, to fix the wire so that the little bent arms shall point not upward or downward, but sideways, when the cross is horizontal. The points of sewing-needles may also be employed for the bent arms. A little bit of straw is stuck into the cross at the centre, to form a cap. This slips over a sewing-needle, $N$, supported by a stick of sealing-wax, A. Connect the sewing-needle with the machine, and turn. A wind of a certain force is discharged from every point, and the cross is urged round with the same force in the opposite direction.

You might easily, of course, so arrange the points that the wind from some of them would neutralize the wind from others. But the little pointed arms are to be so bent that the reaction in every case shall not oppose, but add itself to, the others.

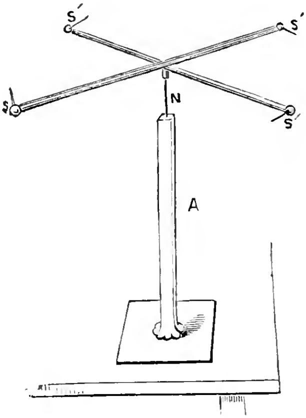

FIG. 21.

The following experiments will yield you important information regarding the action of points: Stand, as you have so often done before, upon a board supported by four warm tumblers. Hold a small sewing-needle, with its point defended by the forefinger of your right hand, toward your Dutch metal electroscope. Place your left hand on the prime conductor of your machine. Let the handle be turned by a friend or an assistant: the leaves of the electroscope open out a little. Uncover the needle-point by the removal of your finger: the leaves at once fly violently apart.

Mount a stout wire upright on the conductor of your machine; or support the wire by sealing-wax, gutta-percha, or glass, at a distance from the conductor. Connect both by a fine wire. Bend your stout wire into a hook, and hang from it a tassel composed of many strips of light paper. Work the machine. Electricity from the conductor flows over the tassel, and the strips diverge. Hold your closed fist toward the tassel, the strips of paper stretch toward it. Hold the needle, defended by the finger, toward the tassel: atctration also ensues. Uncover the needle without moving the hand; the strips retreat as if blown away by a wind.

And now repeat Du Fay's experiment which led to the discovery of two electricities. Excite your glass tube, and hold it in readiness, while a friend, or an assistant, liberates a real gold or silver leaf in the air. Bring the tube near the leaf: it plunges toward the tube, stops suddenly, and then flies away. You may chase it round the room for hours without permitting it to reach the ground. The leaf is first acted upon inductively by the tube. It is powerfully attracted for a moment, and rushes toward the tube. But from its thin edges and corners the negative electricity streams forth, leaving the leaf positively electrified. Repulsion then sets in, because tube and leaf are electrified alike. The retreat of the tassel in the last experiment is due to a similar cause.

There is also a discharge of positive electricity into the air from the more distant portions of the gold-leaf, to which that electricity is repelled. Both discharges are accompanied by an electric wind. It is possible to give the gold-leaf a shape which shall enable it to float securely in the air by the reaction of the two winds issuing from its opposite ends. This is Franklin's experiment of the Golden Fish. It was first made with the charged conductor of the electrical machine.

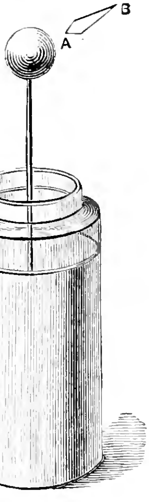

Fig. 22

M. Srtsczek revived it in a more convenient form, using instead of the conductor the knob of a charged Leyden-jar. You may walk round a room with the jar in your hand; the "fish" will obediently follow in the air an inch or two, or even three inches, from the knob. (*See A B*, Fig. 22.) Even a hasty motion of the jar will not shake it away.

Well-pointed lightning-conductors, when acted on by a thunder-cloud, behave in the same way. The opposite electricity streams out from them against the cloud.

Franklin saw this with great clearness, and illustrated it with great ingenuity. The under-side of a thunder-cloud, when viewed horizontally, he observed to be ragged, composed of fragments one below the other, sometimes reaching near the earth. These he regarded as so many stepping-stones which assist in conducting the stroke of the cloud. To represent these by experiment, he took two or three locks of fine loose cotton, tied them in a row, and hung them from his prime conductor. When this was excited, the locks stretched downward toward the earth; but, by presenting a sharp point erect under the lowest bunch of cotton, it shrunk upward to that above it, nor did the shrinking cease till all the locks had retreated to the prime conductor itself. "May not," says Franklin, "the small electrified clouds, whose equilibrium with the earth is so soon restored by the point, rise up to the main body, and by that means occasion so large a vacancy that the grand cloud cannot strike in that place?"

## HINTS FOR THE SICK-ROOM.

WHEN a woman thinks of making deliberate choice of the profession of a sick-nurse, she can, of course, take into careful consideration if her character and temperament are or are not suited for so arduous and trying an avocation. If she is a person of excitable nature, and possessed of but little self-control, she can be wisely counseled to give up the idea of a life for which she is so thoroughly unfit; but no peculiarities of character or temperament can exempt a woman from being called upon by the plain voice of duty, at one time or other of her life, to take her stand by the bedside of one dear to her, and soothe as best she may many a weary hour of restlessness and pain.

Very few, indeed, are the women who escape this rule—most have to take upon themselves the burden of attendance in a sick-room—and perhaps there are few subjects upon which the generality of women are so well-intentioned, and yet so ignorant. With the very best and kindest meaning in the world, attention bestowed upon a suffering person may be productive of more discomfort than comfort to the patient, and endless annoyance to the physician, just because the zealous, but alas! untrained and undisciplined volunteer does everything the wrong way.

Again, from a mistaken and unreal idea of true delicacy and refinement, many women shrink from ever seeing or learning anything about suffering or sorrow; and so, when the inevitable fate brings the sights and sounds of pain, the dreadful realities of death, cruelly home to them, they are paralyzed by terror, and useless, nay, worse than useless to those most dear to them. Even as I write, sad instances rise before my mind of a lack of moral courage, an utter impossibility of self-command, that has led the mother to flee from the bedside of her dying child, the wife to turn away from the failing sight that yearns to gaze upon her face while life yet lingers! The contemplation of pain could not be borne, because the mind was weakened and enervated by a selfish habit of yielding to the dislike of bravely facing anything disagreeable. Let all true women train themselves to possess self-control, calmness, and patient courage; let them strive to acquire a certain amount of knowledge of the cares and duties of the sick-room; let them not shrink from hearing the details of this or that form of suffering and disease, and gladly and readily offer help (when they rightly and safely can) outside the bounds of their own immediate home circle. Let them rejoice in any fitting opportunity that may come in their way of perfecting themselves in this, the highest and holiest of woman's duties, so that when their own time of trial comes they may not fail!

Taking it for granted that there are many who will gladly take a few plain and practical hints on this subject, I shall condense the result of a somewhat long and wide experience into a short space.

And, first: It is in things which of themselves appear trifling, and even insignificant, that the comfort of a sick-room is made or marred. For instance, an energetic and amiably-intentioned person places a cold pillow beneath the shoulders of a patient suffering from pneumonia, that is, inflammation of the lungs; a fit of coughing, perhaps a restless night, is the result. Five minutes' warming of the pillow at the fire would have prevented all this mischief, and even conduced to sleep.

Dress, again, is a matter of great importance in a sick-room, and here I must enter a protest against that very common practice of the amateur sick-nurse making a "guy" of herself. I really have seen such startling and unpleasant costumes donned "for the occasion," as seemed to me enough to cause delirium in the patient, if long contemplated—shawls, and dressing-gowns, and wraps, of such an obsolete and awful character, that the shadow of the watcher, cast upon the wall by the dim light of the night-lamp, must form a horrible "old granny," and be by no means a *pleasing reflection* to meet a sick man's eyes, as he wakes weak and confused from an opiate-won sleep!

The best dress for a sick-room is plain black—for the simple reason that no stain shows upon it—an old silk is the most economical, but silk rustles, and is therefore objectionable. Black lustre is very serviceable—not made long enough to trail, upset chairs, and get under the doctor's feet; and not having hanging sleeves, but fitting close and neat at the wrist, so as to be finished off by nice white linen cuffs. (I have seen a hanging sleeve catch on some projecting point of chair or table, and convert a glass of egg-flip into a "douche" externally applied, swamping the patient in a yellow sea, besides sending her into hysterics.) A habit of moving quietly about the room, and yet not treading "on tiptoe" and making every board in the floor creak its loudest, is also very advisable; and nothing can be better by way of foot-gear than those soft, warm felt boots now so common; they both keep the nurse's feet from becoming cold, and make the least possible sound in moving about. Of course the manner of speaking in a sick-room is all-important. Oh, the horror of that dreadful "pig's whisper," which penetrates to the inmost recesses of the room, and wakes the sleeping patient as surely as the banging of a door!

I call to mind a case of fever—a very bad case, in which sleep was the one desideratum—almost the only hope. The sufferer had fallen into a doze—the terrible throbbing of the arteries in the bared throat seemed a little less rapid—the fire that was burning life away raged a little less fiercely—but, some idiot peeped in through a half-closed door, and with horrible contortions of the visage, intended to express extreme caution, whispered in blood-chilling tones, "How—is—he—getting—on—now?"

In an instant the patient had raised himself in bed, the poor hot hands were thrown out to ward off he knew not what—the filmy eyes stared wildly round—the parched tongue faltered: "What is it? Where is it?" And for hours the weary head tossed from side to side, and meaningless words fell on the ears of those who watched and waited, and almost feared to hope. And yet it was meant in kindness!

In some of the most severe diseases, such as cholera and diphtheria, the patient is often *intensely* conscious of all that is passing around him. The wish to know everything that is said and done is extreme, and nothing excites a patient so much as anything like whispering and mystery. The natural voice, only so much lowered as to be perfectly distinct, is, then, the proper tone for a sick-room. If silence is needed, let it be complete, and no whispering permitted either in the room, or, worse still, outside the door.

And now I must say a few words on a disagreeable but yet most important subject. In any case where operative surgery is necessary, it cannot be too strongly insisted upon that no one shall remain present whose calmness and self-control are not a certainty. I remember well a delicate and difficult operation having to be performed—not a painful one, but where success mainly depended on the perfect stillness of the patient. Scarcely had the first slight incision been made, when the room resounded with the moans and cries, not of the sufferer, but the friend who had kindly come to support her through the ordeal! With many a sob, and choke, and gurgle, the friend was assisted from the room, and then all went well enough; but great delay, and much increase of nervousness on the part of the patient, naturally resulted.

One of the many very eminent surgeons of whom America can boast once told me that on the occasion of performing a most formidable operation, in which promptitude was a vital necessity, he saw, at a moment when seconds were precious, a friend, who had insisted on remaining present, suddenly turn deadly pale, and fall fainting on the floor, in uncomfortably close proximity to the chloroformed patient. Dr. B—— stooped down, and quietly rolled the insensible individual into a corner of the room, where he enjoyed undisturbed repose until such time as some one had time to "bring him to."

Thus it may be seen that any one who is in the least nervous, and cannot be certain of his own powers of self-command, acts with truer kindness in remaining absent from such scenes, than by becoming an added source of anxiety, where there is so much already of the gravest character. If, however, a woman has the moral courage to face such trials calmly, and without flurry—if she can do simply what she is told, and *nothing more*—if she can hold her tongue—wholly dismiss herself from her own mind, concentrating all her attention on the patient, she may be of untold help and comfort. On the other hand, a sick-nurse who asks the doctor endless questions—who presumes in her ignorance to criticise his treatment—who is spasmodic in her sympathy, and ejaculatory in her lamentations, is pestilent in a sick-room, and should, if possible, be got rid of at any cost.

But as well as the nervous and excitable nurse, there is another species of the genus against whom I would warn any one who in the least values his own comfort, and that is, the person who insists upon "helping you" to nurse some very severe case, and never ceases assuring you that she "keeps up splendidly at the time, but afterward—;" and then comes an ominous shake of the head, which is a ghastly intimation of what a time you will have of it with her, when what she is pleased to call the "reaction" sets in. Nothing can be more aggravating than to contemplate such an individual, and look forward to the "breaking-down" which she assures you is inevitable, and which you feel assured will come just when you and everybody else are tired out with nursing the real sufferer, and when you want to go to bed, and sleep your sleep out. The very idea of having to put hot-water bottles to her feet, and mustard-poultices to her side, and cooling lotions to her aching brow, and watch her acting the martyr (the while you are wishing her at Jericho, or some other equally hard-to-get-back-from place), is not a pleasant anticipation, as you sit opposite to her through a long night of watching, and she tells you, with a melancholy yet vainglorious countenance, how she shall "pay for this afterward." But she treats with scorn your suggestion that she should go to bed—indeed, she would be bitterly disappointed if she might not immolate herself—and you. This sort of thing is what I call "selfish unselfishness," a kind of self-sacrifice that is always acting as its own bill-poster.

But there is one kind of nervousness which I do not think meets with sufficient consideration, and that is the unconquerable fear which you will find some people have of any disease that is infectious. Now, I think this sort of fear is far more constitutional than mental, and it appears to me most uncharitable to speak of those who are thus nervous by temperament as "so frightened," etc. Depend upon it, if any one has a great dread of infection, he is far better away from the chance of it. If I heard a person express a great and overpowering dread of small-pox, cholera, fever, or diphtheria, I should do all in my power to prevent that person going near any case of the kind, because I should be morally certain of the result. As a rule, I believe that those who are perfectly fearless are comparatively safe; and there is no truer test of perfect freedom from nervous dread than the fact of being able to sleep at once, quietly and naturally, and without the mind being obliged to dwell upon the work of the day. The best cholera-nurse I ever saw used to tell me that she often sat down in the corner of a room, on the floor, and "slept right off" for half an hour at a time, either day or night, just as such opportunity for rest presented itself. But of course there are exceptions to all rules; and one of the most devoted and the most fearless in attendance on the sick, during a terrible epidemic, died just when the worst of the battle seemed over.

But to return to some of those "trifles," the knowledge of which is so needful to those who would try to fulfill well the duties of an amateur sick-nurse.

When active personal care of a sick person is undertaken, the finger-nails should be kept very short. I have seen a long nail tear open a blister, and expose a raw surface, causing great pain. For the same reason, all removable rings should be taken off; and any ornaments that hang loose and make a jingling noise are best dispensed with, as they irritate and annoy a sensitive patient.

It seems to me that this very unpretending paper will be hardly complete without a few words as to the diet that is best for any one acting as sick-nurse in a long and trying case.

One great point is, to let no silly notions of sentiment prevent you making a practice of taking substantial and regular meals; and, when you have to sit up all night, be sure and have food at hand, and never go more than three hours without eating. Now, I am going to say what I know many will highly disapprove of, and it is this: when you are nursing a long and anxious case, and you want to be able to "stay" to the end, *avoid all stimulants.* There is nothing you can do such hard work upon, there is nothing that will support you in long-continued watching and fatigue, like good, well-made coffee. Stimulants only give a temporary excitement, that passes itself off as strength. They injure that clearness of thought, that perfect quietude and recollectedness which are so essential to the good sick-nurse;

and they tend more than anything else to that miserable "breaking-down afterward" of which I have already spoken.—*Chambers's Journal.*

# THE POLAR GLACIERS.

By C. C. MERRIMAN.

## II.

THE element of all others most sensitive to the changes and impulses of every kind of force is the earth's atmosphere. It is in a state of constant disturbance, and seems to be obedient to no laws or regularity. Yet, unstable as the winds appear, they are really, in their general movements, among the most orderly and effective agents in Nature. This is shown in a remarkable manner by their agency in impelling the great ocean-streams, and therefore their important influence on glacial phenomena. In order to make this evident, it will be necessary to explain in brief the general laws of their circulation.

The earth turns on its axis from west to east, and with it rotates daily the enormous envelope of the atmosphere. The velocity of rotation at the equator is something over 1,000 miles an hour; at thirty degrees distance it is about 150 miles an hour less. In higher latitudes it is still less; and at the poles nothing. Therefore, whenever the air moves north or south on the surface of the earth, it will carry with it a less or greater velocity of rotation than the places it passes over, and will turn into an easterly or westerly wind, according as it approaches or recedes from the equator. In the region of the sun's greatest heat, the air, rarefied and lightened, is continually rising, and cooler currents come in on both sides to take the place of the ascending volume. As these side-currents come from a distance of about thirty degrees from the equator, they have, at starting, an eastward velocity many miles an hour less than the localities they will eventually reach. Consequently they will appear to lag behind in all the course of their progress to the equator—that is, they will have a westerly motion united with their north and south movements. These are the great trade-winds, blowing constantly from the northeast on this side, and the southeast on the other side of the equator.

But the heated air, which has risen in immense volumes in the tropics, spreads out to the north and the south in the upper regions, passes entirely over the trade-winds, and comes down to the earth in the temperate zones. It, however, continues to have the velocity toward the east which it acquired at the equator, and, when it strikes the slower-moving latitudes, it will be traveling much faster than the regions it comes down upon. Hence the westerly winds that prevail almost constantly in the middle latitudes.

This is the normal order of the wind-currents, and that which would prevail with nearly perfect regularity if the world were a uniform globe of water or of land, and equally heated on both sides of the equator. But the continents, and particularly mountain elevations, produce great disturbances—unequal rainfalls and ever-varying atmospheric pressures. When also, from any cause, one of the trade-winds, notably the southern, is increased in its violence, so as to push a tornado-tongue across the dividing line, into the opposite system of winds, there is started one of those cyclones, or great circular storms, which ravage the tropics and whirl through the temperate zones, finally exhausting themselves in the higher latitudes to the eastward.

The southern hemisphere is at the present time colder than the northern, owing primarily to the fact that the winters there are eight days longer than the northern, and the sun, during those seasons, about 3,000,000 miles farther from the earth than during the northern winters. The difference of temperature, therefore, between the warm air that rises at the equator and the cold air that comes in from the south is greater than that on the north side. And, as it is difference of temperature that produces the whole movement of the air-currents, of course the greater strength of that movement must be on the southern side. Hence the larger share of the equatorial current passes over to the south, and the southern trades are much the strongest. In accordance with this theory, it is a matter of observation that the southern trade-winds reach across the equator and into the northern hemisphere in some places ten to fifteen degrees.

In obedience to and perfect accord with this great system of winds, the waters of the oceans move. The strong southeast trades blow up from Southern Africa, cross the equator, and drive the waters of the South Atlantic into the Caribbean Sea. The lighter northeast trades, blowing between North Africa and the West Indies, assist and give direction to this movement, which finally impels through the Straits of Florida a tide of tropical waters a hundred times greater than the outflow of all the rivers in the world. This great flood of thermal waters spreads out in the Northern Atlantic, imparting to Europe a climate corresponding to countries twenty degrees south of it on this side of the ocean. There is, of course, an under-current from the Arctics to the equator, exactly compensating this enormous northward flow of the surface-waters. The same process and effect are repeated in the Pacific Ocean; and the great Japan Stream robs the southern hemisphere, for the benefit of our Pacific States, only in a degree less than does the Gulf Stream for the benefit of Europe.

A change in the relative strength of the trade-winds, such that the northeast trades would blow across the equator into the southern hemisphere, would entirely reverse the course of the warm ocean-currents, and carry to the southern continents the heat abstracted from the northern. Such a change in the course of ocean-streams has unquestionably followed every change in the glaciation of the hemispheres from astronomical causes. The winds and the water-currents have always helped to increase the difference in temperature which a considerable eccentricity of the earth's orbit must always have produced between the northern and southern halves of our globe. It matters but little which of the two—the ocean-currents or the astronomical causes—have produced the greater effect, since it is certain that they have ever coöperated in one and the same direction.

On all the tropical seas, between the terminal lines of the two trade-winds, there is what is called the belt of calms, a tract averaging from 300 to 500 miles wide, in which, whatever winds there may be, are exceedingly light and unreliable. It is here, as we have seen, that the air and vapor, heated by the vertical rays of the sun, are continually rising and spreading outward in the upper regions. It is a complete dividing line between the climates of the two hemispheres. One may be frigidly cold, while the other is highly heated; the only difference being that the calm belt would be removed farther into the warmer hemisphere. It now ranges from five to ten degrees of latitude on this side of the equator. In this belt of ascending air-currents is carried up the greater part of the moisture which afterward descends as rain or snow far from the equator. Whatever excess of solar heat there may be on the tropics is here absorbed in evaporating water. To vaporize a pound of water, according to Prof. Tyndall, requires as much heat as to raise fifty-five pounds of ice-water to the boiling-point. It is manifest, therefore, that there must have been, during the glacial periods, an enormous amount of sun-power somewhere on the face of the earth to have supplied the vapor that buried one zone and half of another beneath a solid ocean of ice.

These facts effectually do away with all the theories, except the astronomical, which have been advanced by physicists to account for glacial phenomena: one, that our solar system has, during certain ages, passed through a colder region of space; another, that the sun in glacial times for some cause failed to supply his usual quantity of heat; and, as a consequence of either, that the glaciation of both hemispheres occurred at the same time. Equatorial heat is as necessary to a glacial period as polar cold. The one transforms the waters to vapor and elevates it to the cloud-spheres, while the other sends in the cold winds beneath, which compel the vapors to come over to the frozen side and build up the glacier.

The system of the stratified rocks has been called the great geological book, with its uncounted leaves overlying each other. Now, as it is a part of the glacial theory that each of these leaves or strata, at least in greater part, was the work of a glacial period, it is important for us to examine closely and particularly the course and effect of one of these great cycles of 21,000 years or thereabouts. We will take, for example, that one of the Post-tertiary glacial which was of the greatest extent and severity. Ten cycles back—about 210,000 years ago—one of the periods of maximum eccentricity had just commenced, the highest since four times that number of years. The perigee, or nearest approach to the sun, happened then as now, a few days after the winter solstice of our half of the world. It was the great summer of the northern hemisphere. But over the southern hemisphere at this time, almost if not quite to the tropics, extended one vast sheet of ice. It reached far into Brazil, it covered Southern Africa, and lapped over on Australia. The marks are all there, scored on the solid rocks, to show how it crept up the southern slopes of the hills, and how far it pushed its icy arms. In South America at least there is ample proof that the great glacier spanned the southern ocean to reach it; for the furrows on the rock-beds of Patagonia are from the pole toward the equator, whereas in any other case they would have been from the mountains to the sea. With such a state of things at the southern end of the world, with probably miles in depth of ice and sea in its higher latitudes, there could have been but little water left for the opposite northern regions. What is called the Atlantic-cable plateau, between Newfoundland and Ireland, was very possibly the north shore of the Atlantic Ocean; and probably no considerable bodies of water existed anywhere north of that parallel. The present continents were all mountain tablelands, far from the vicinity of evaporating surfaces. Like all such elevated regions not exposed to specially moist winds, they were doubtless dry and arid deserts. However warm may have been the climate of the north temperate and arctic zones during this their great summer, their great elevation and the want of any kind of water-supply must have made them barren of all forms of animal or vegetable life. Consequently there would be, as is notably the case, but few if any traces of this part of the great season left in the geological records, at least above the present seas.

Five thousand years pass, and the perigee has advanced to meet the vernal equinox. The spring season is now the shortest of all; but, as the autumnal is correspondingly lengthened, the average climate is about that of the present time. But it is the season of the great thaw—the breaking-up time—of the southern hemisphere, and the waters are returning to fill the northern ocean-beds. Imperceptibly a permanent white cap begins to fasten itself to the heights of the boreal zone, to extend its outline, and to increase its depth. Slowly the lands are being submerged and the oceans broaden out, till there comes a time when land and water are equalized in the two hemispheres, and the climates are substantially alike.

Another 5,000 years pass, and the perigee now coincides with the summer solstice of the northern hemisphere. This is the position there of greatest cold: the winters are twenty-eight days longer than the summers; and the extra days are in great part those of the briefest sunshine. Besides this, the earth is 10,500,000 miles farther from the sun in winter than in summer. According to the most careful calculations, the temperature of extreme northern regions would be lowered 50°, and the mean annual range would be fully 60° below zero. This in all probability would carry the isothermal line of Labrador, South Greenland, and Iceland (32° Fahr.), down to Charleston and the Gulf of Mexico. The late Prof. Agassiz found ice-marks as far south as this, though it can hardly be supposed that the permanent glacier extended so far. There are, however, abundant signs of the permanent ice-layer all over the State of New York, and both east and west of it. The same distinguished authority was wont to claim in his lectures that all the beautiful north and south lakes of Western New York—the Cayuga, the Seneca, the Canandaigua—were ploughed out of the solid rock and walled around with their clay and gravel hills by advancing and retreating glaciers. The rocky summits of New England are found to be grooved and scored all over their sides and tops with markings always in nearly a north and south direction. They have been traced on Mount Washington to within 300 feet of the highest point. There can be no doubt that at the time we are writing of, about 200,000 years ago, there was one solid ice-stratum of immense thickness—Agassiz said from two to three miles—slowly being pushed from the northward by the power of freezing water, over all of New England and the lake States.

Again the perigee proceeds to meet the autumnal equinox. The winter and the summer seasons have again become equal in length; and the sun is just half its time on the north side of the equator. The great ice-shroud is now being gradually withdrawn. Where it abuts on deep waters, enormous icebergs are broken off and float away to the south, carrying bowlders and soil and whatever it may have picked up in its slow course down to the sea. Where it terminates in shallow waters or on the land, its effect is to produce such an arrangement and diversity of soils and such a peculiar outline of country as no other agency could ever have brought about. So different is the nature and work of the great polar glacier from anything with which we are familiar at the present day, that it has seemed to me to require a few words of more particular description.

As is well known, the glacier is an accumulation of many winters' snows consolidated by pressure into a clear blue ice. In this condition it manifests the peculiar property of viscous bodies—it is in continual slow motion in the direction of least resistance. Whether it is by the expansion produced by the repeated thawing and freezing of water in its interstices, as Agassiz claimed, or whether by the pressure of the mass and glacial regelation, which is the constant freezing together of ice-surfaces in contact, after breaking under unequal pressures, or crushing against obstacles, which is the theory of Prof. Tyndall, or whether by both causes combined, certain it is that large bodies of ice not only flow like a heavy lava-stream, conforming themselves to all inequalities of the surface, but they also scrape along in solid mass, as if pushed by some irresistible force from behind. Mountain-glaciers show both motions. But the great polar glacier, extending over comparatively level surfaces, seems to have been pushed bodily outward from its fixed polar base, and to have moved almost entirely under the mighty impulse of expansion. The parallel scratches and furrows which, in our hemisphere, mount straight up the north sides of mountains; the worn and rounded appearance of those sides and of the summits, as compared with the rough, unsmoothed southern slopes; the erratic blocks, or some peculiar specimens like the native copper of Lake Superior, carried almost directly south for scores or hundreds of miles, over heights, and even over arms of the sea—all show conclusively that the great glacier pushed its meridional course over all obstacles and to long distances.

Imbedding in its under surface the grit and gravel on which it froze, this mountain grindstone grated and ground the solid rocks over which it passed into the various materials of soil. Sand and gravel were the products from granitic rocks and sandstones, clay from the slates and shales, and loam from the softer lime-rocks. But the most striking effects which the polar glacier produced were the long ridges of gravel and bowlder-clay hills which it scraped up as it advanced, and left at the end of its journey, or at each halting-place of its retreat. For it must be borne in mind that the glacier was still pushing southward all the time that it was, on the whole, retreating. These terminal moraines are either the promiscuous gatherings of clay and bowlders and earths of all kinds, or, if they have been subjected to the sorting influence of moving waters, they are gravel hills with sandy bases, and clay flats extending usually to the southward of them. They run in somewhat parallel courses easterly and westerly, sometimes hundreds of miles. Great numbers of these concentric ridges may be counted in Western New York, between the long Lake Ontario ridge and the lake hills of the south part of the State. Several cross the New England States, one running along the coast of Maine, and westerly through the White Mountains. In addition to these are the lateral moraines, running in an opposite direction. These were, some of them, pushed out at the sides by outstretching arms of the glacier; others were formed by streams running down through breaks or fiords in the melting ice-sheet. So extensive and so marked are the traces of the great polar glacier over all middle latitudes, both north and south, that it may truly be called the great landscape-gardener of the temperate zones.

But it is natural to conclude that, if there has been one glacial era caused by astronomical cycles, there must also have been others in earlier geological times. And, as we turn back the pages of the great earth-book, we find therein recorded the evidences of the vicissitudes of climate which we thus anticipate, but, if we mistake not, in continually-lessening force and extent the farther back we go. For, long ages previous to the recent glacial epoch, through all the Tertiary era, the fossil plants and animals indicate the prevalence of a warm and genial climate over the greater part of the globe. Then come the chalk-beds of the Cretaceous period, in which are frequently found water-worn blocks of granite and aggregations of pebbles, proving that then, as now, the iceberg floated down from the north over seas that were quietly depositing the chalk-shells. Still older is found a long series of secondary strata, the Oölite, the Lias, and the Trias, which were deposited in at least sub-tropical climates. They are the burial-grounds of the enormous saurian reptiles that once had an age all to themselves in the world's chronology. Their remains have been found within a thousand miles of the north-pole, thus proving that warm seas covered every zone.

Between the great divisions of Secondary and Primary in geology, there lies a stratum found only in the higher half of the latitudes, and known as the Permian or New Red Sandstone. The scanty life-forms found in it, and the coarse grit and angular bowlders of which it is composed, evince the well-known glacial action. Geologists generally think that there elapsed between these great divisions a very long period of time in which, excepting the sandstone, but little was done one way or another to build up the crust of the earth or leave a mark in its records. This doubtless indicates periods of very small eccentricity. Such periods did occur, according to Mr. Croll's calculations, immediately before and after the great eccentricity of 850,000 years ago, in which we may perhaps conjecture the New Red Sandstone to have been formed.

Previous to this age were the long Carboniferous periods, during all of which a warm and moist climate prevailed over all lands that have yet been explored. Below the coal-measures are found again the grits and bowldery conglomerates of the Old Red Sandstone, which, with great paucity of organic remains, would imply the alternations of somewhat glacial climates. The Silurian, Cambrian, and Laurentian systems preceded the Old Red in the order named, and reach back to the dawn of life on the earth. These formations are of vast thickness, and were deposited at the bottom of warm seas in all parts of the world.

It cannot be denied that, as we go back in the geologic records, we find more and more the evidences of greater heat and a more equable climate. It is certain that the astronomical relations which we have pointed out—the revolutions of the orbital points and the alternations of great and small eccentricity—have never ceased to exist. Therefore, if the world had been subjected to only the same solar heat in ancient as in recent periods, there must have been repeated glacial epochs; and we should find the bowlder, and the unsorted drift, and the scratched and polished rocks, all through the stone presentations. But very few, if any, such evidences have been found.

Again, for a warm and exuberant climate to extend into the arctic zone, there was necessary one of those great summers of considerable eccentricity, without the excessive drainage, which an unusually large accumulation of ice in the opposite hemisphere would necessitate. Each summer cycle of coal forests, or of reptile monsters, implies, not only a long visit, and a high evaporating power of the sun, but also the addition, to the opposite polar regions, of a weight of ice only sufficient to draw the waters from a small part of the low and flat lands of the warmer hemisphere. We have seen that periods of warm, perhaps even tropical climates in polar latitudes, intervened between the great winters of the last glacial epoch. But they have left scarcely a trace in the strata. They were the nearest approach possible, with the sun-power of recent times, to the conditions which of old brought out such a profusion of animal and vegetable life. But the only result in the later periods was, that the earth was unbalanced. All the waters were either turned into ice, or were following after it toward one of the poles. One side of the world was a frozen waste, while the other was a burning waste.

I think we cannot avoid the conclusion that the sun shone with a far intenser power on the Carboniferous swamps and the Oölitic shoals than on the gravel-hills of the Drift; that the oceans of early times were wider and warmer than now, and circulated more freely between the tropics and the polar seas; and that the heated and moisture-laden atmosphere retained the heat and equalized the temperature between the equator and the poles far more than at present.

With these conditions, that is, with a greater sun-power and a considerable eccentricity of the earth's orbit, I can conceive a rational explanation, that which I have not yet seen in the books, of the formation of the coal-layers, alternated as they always are with marine deposits. These alternations are sometimes very numerous. There are as many as sixty distinct veins of considerable thickness, one over another, in the coal-mines of South Wales, as also of Nova Scotia. There must have been, in that case, sixty periods of dry land, each of sufficient duration to grow many forests, and each followed by a long-continued submergence, in order that each layer should become fossilized, and buried beneath a shale or a limestone, which could only have formed in the depths of a quiet sea. The books say there were so many upheavals, and a like number of subsidences, alternating with each other. As if Old Earth had bent her back, for her load of pit-coal, threescore times among the Welsh hills, and again as many more at Halifax. It is a far more reasonable explanation, that each considerable layer of coal indicates a cycle of long summers, and the withdrawal of a moderate depth of the oceans from one hemisphere to the other, by reason of moderate accumulations of ice in polar latitudes, and the return, again, of the waters after 10,500 years. In this way, and in no other that I can conceive of, can be fairly explained the constant mixture and alternations of terrestrial and marine relics, all through the fossil-bearing formations, and the hundreds, if not thousands of different and distinct strata which are found lying one above another.

Whoever, even cursorily, studies the phenomena of geology, must be impressed with the enormous length of time it has taken to arrange the terrestrial substructure, and prepare it for the higher forms of life. Even the comparatively recent period of the Bowlder Clay, which laid out the grounds of the present area of civilization, dates back for its commencement, as we have seen, probably 200,000 years. If it might be assumed that the Permian or New Red Sandstone was formed during the next previous period of extraordinary eccentricity, which was 850,000 years ago, then the Devonian or Old Red Sandstone would come in, very appropriately, at the next anterior era of extraordinary focal distance, which occurred 2,500,000 years back. The Carboniferous period, which came between these two, could not have been formed in less than 1,000,000 years, as most geologists concede; and by calculations previously indicated, those sixty Welsh layers of coal, if there are that many, divided off by marine deposits of considerable thickness, would have consumed 1,250,000 years.

The average thickness of all the strata that lie above the Old Red Sandstone is not far from two miles. But this formation is itself, in many places, two miles thick. And the lower Primary systems will add at least ten miles to the vertical measure of the fossil-bearing rocks. It is estimated that "the fossiliferous beds in Great Britain, as a whole, are more than 70,000 feet in thickness;" and many that are there wanting, or nearly so, elsewhere expand into beds of immense depth. There are certainly fifteen miles deep of strata to be accounted for—the slow accretions of the ages—mainly ocean-sediment that has come down from the wear and washings of the solid rocks. It would be by no means a bold assumption to say that 20,000,000 years had elapsed since the eozoön first built its reefs in the warm Laurentian seas.

# AXES AND HATCHETS, ANCIENT AND MODERN.[1]

BY THE REV. ARTHUR RIGG, M. A.

TOOLS with cutting-edges are not only numerous and varied in form, but they are also varied in the purposes for which they are formed, and in the mode of using. Hence no very precise statement of what is generally meant by a "cutting-edge" can well be

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[1] From a lecture delivered before the London Society of Arts.

given. Three classes, however, of such tools may be marked out, and into one or other of these it is probable all those tools which can properly be defined as tools with cutting-edges may be arranged.

A first class will comprehend tools which meeting the work at a particular angle continue the path of each portion of the edge in the same straight line. Axes, adzes, gouges, chisels, and planes (as ordinarily used by carpenters), belong to this class. Such tools are brought into action either by impact or by direct thrust. The adaptation of machinery to tools in this class is easy, because the cutting-edge has to describe only a straight line, and this done once, if the place of application be removed, a repetition of impact or thrust in the same direction will suffice.

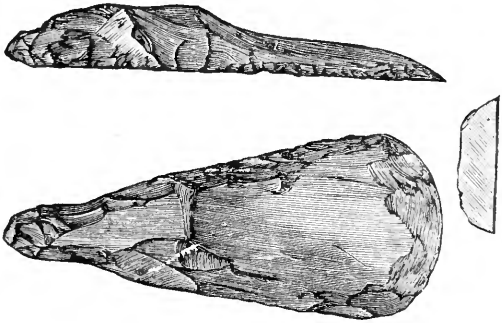

Fig. 1.—Adze of Flint.

A second class will comprehend tools which, while as a rule retaining the angle at which they are applied to the work, the path of any portion of the tool is not a straight but a curved line. Tools of Class 2 are seldom acted upon by direct impact, or simple thrust. To adapt them to machine-work requires either a compound motion in the tool, or a motion compounded of the tool and work. When used as handicraft tools, this compound motion is derived from the muscular actions of the body of the workman, or the mechanical contrivances of construction in the tool. Knives, shears, razors, and saws, belong to this class. And to this class belong those tools in which what are mechanical contrivances for causing a "draw cut" are introduced, e. g., certain garden and pruning shears, also, hay and bread cutting knives. There is a motion in the human jaws which gives to the cutting teeth this "draw cut," and so they separate what is between them as draw-cut scissors might do. Indeed, all tools in this class operate most efficiently when acting upon the "draw-cut" system.

Hence, while certain of the human teeth belong to Class 1, others belong to Class 2. The contrivance in the jointing of the lower jaw to the upper in man is a compound one, adapting itself to three motions, one or other of which is found in many tools. There is up-and-down motion, enabling certain of the teeth to cut meat as nippers do. There is also a backward-and-forward motion, producing a saw or file like operation, and there is a lateral or side motion, producing such a result as that of grinding. It is probable that, from observation on the action of the teeth, the "draw cut," so essential to the perfection of tools that really *cut*, has been suggested.

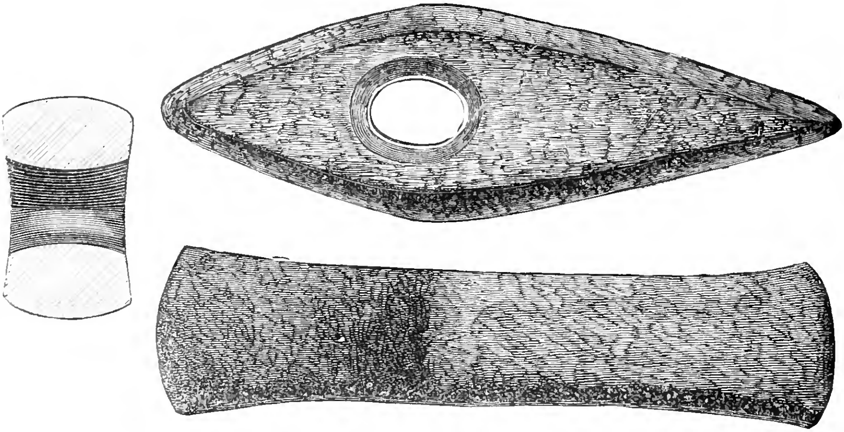

Fig. 2.—Double-edged Axe of Greenstone.

Class 3 will comprehend those tools in which rotation is more usual than rectilineal motion. The tools in this class are constructed on principles allied to those in the two former classes. All drilling and boring tools belong to this class.

The action of tools with cutting-edges in Class 1, being the most simple, had better be first considered. As axes and adzes belong to this class, and as the structure of habitations probably led our ancestors to the formation of tools, doubtless that form of cutting-instrument which most commended itself to these primitive artificers would be the first to be constructed. Passing by the very early form, we may commence with a consideration of the edge of the axe or adze, when that edge became part of a constructed implement, and not a mere piece of sharp-edged flint. The construction essential to the tool is a handle, or, as it is called, a "helve." The shape of this helve, and the mode in which the head or metal of the axe is attached to it, are well worthy of some preliminary attention.

Perhaps here may be drawn the distinction between narrow and broad axes and hatchets. Axes are tools to be used with both hands; they have long handles, and may be swung as sledge-hammers. Hatchets are to be used with one hand, have short handles, they are much lighter and thinner than axes, and are employed more in the trimming than in the hewing of timber. Both narrow and broad axes are employed in forestry, the woodman's choice being affected by the size of the timber and the character of the fibre. A hatchet is handled with the centre of gravity nearer the cutting-edge than the line of the handle; an axe with the centre of gravity in the line of handle produced. Of this, however, more hereafter.

The mode of attaching a handle to an axe in the bronze age is very instructive to us. The illustrations are suggestive enough, and need only a passing remark. It will be observed that for the purpose of handling, some of these axes are socketed, others wedge-pointed. The socketed ones were evidently handled as we handle socketed chisels. There is, however, one peculiarity, and that worthy of consideration. These bronze hatchets have in many instances a semicircular, ring-like projection (*see* Figs. 4 and 5), the object of which was for a long time a puzzle, but the suggested mode of handling the implements, if correct as seen in the diagram, points to a knowledge of directions of tension and of pressure, which engineers at the present day cannot but admire. If any one has ever struck a common hatchet to any great depth into timber, and carelessly endeavored to loosen it by raising the extremity of the handle, he may have found the handle separate from the metal near the junction of the two. Now the withe, or lashing, shown in this bronze instrument, has been put, as we should put it at the present day, in order to strengthen the connection at this, the weakest part.

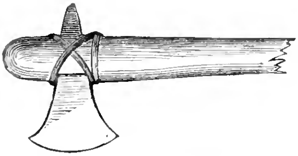

FIG. 3.

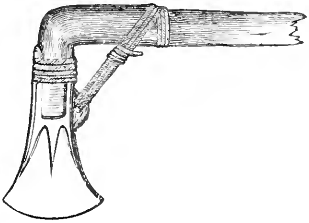

FIG. 4.

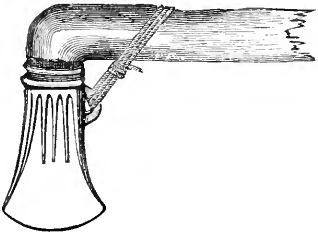

FIG. 5.

Figs. 3, 4, 5, are examples of the modes of handling these ancient bronze hatchets. Fig. 3 is the most primitive. Fig. 4 and Fig. 5 illustrate the mode adopted to strengthen by tension-cords the weakest part of the handle. A remnant of this tension-cord is probably seen in the increased depth now given to the handle, where it enters the eye. It will be noticed that Fig. 5 is socketed as a carpenter's heavy mortising-chisel. The commendable pride of these prehistoric workmen in the beauty of their tools may be inferred from the ornamentation of these bronze axe-blades.

When we pass from the tool and its contrived handle to the mode of using, and the purpose for which it has been constructed, we find, as a rule, a cutting-edge formed by two inclined surfaces meeting at an angle, the bisecting line of which passes through the middle of the metal. It is very apparent that the more acute this angle is, the greater, under the same impact, will be the penetrative power of the axe into the material against which it is driven. This supposition very soon needs to be qualified, for suppose the material offers a great resistance to the entrance of this edge, then the effect of the blow, upon the principle that action and reaction are equal, will react upon the edge, and the weakest, either edge of axe or object struck, must yield. Here, then, primitive experience would be obliged to qualify the simple tool in which the edge was keen and acute, and would naturally sacrifice the keenness and acuteness to strength.

When early uses of the axe are considered, it will be noticed that, even in fashioning with an axe or adze the same piece of wood, different conditions of edge are requisite. If the blow be given in the direction of the fibre, resistance to entrance of the edge is much less than in the blow across that fibre. So great, indeed, may this difference become, that while the axe in Class 1 seems in all respects a suitable tool, yet as the attention of the workman passes to directions inclined to the fibre at an angle of more than forty-five degrees, he will be induced to lay aside the tools in Class 1, and try those in Class 2; for he will have found that while in the one direction of the wood the edge of his axe continues sound and efficient, yet a few blows on the same timber at right angles to this direction have seriously damaged the perfection of the edge, whatever may be the angle at which the faces meet which constitute the edge.

These remarks apply only to tools used in dividing materials, and not to tools used in preparation of surfaces of materials. This preliminary consideration prepares us for the different circumstances under which these two classes of tools may be respectively used. And as the contrast of the effect of the same tool under different circumstances in the same substance is considerable, great also is likely to be the contrast between the edges of the tools and the manner of using them, e. g., the axe, which is the proper tool in the direction of the fibre, is operated upon by impact, while a saw, which is the proper tool across the fibre, is operated upon by tension or thrust, but never by impact.

The mode in which the axe is used will explain why it is unsuited for work across the fibre. The axe is simply a wedge, and therefore arranged to cleave, rather than to cut, the wood. Now, a calculation of the pressure necessary to thrust forward a wedge, and the impact necessary to cause the same wedge to enter the same depth, would explain why (regarded as a wedge only) the handle proves an important adjunct to the arm of the workman. Any one may test this by using an ordinary-handled hatchet on a soft straight-grained wood, or he may take a small axe with a straight and not a curved edge; let it rest upon a lump of moderately soft clay. Add weights until it has sunk to any decided depth, then take the axe by the head, and by pressure force the edge to the same depth. Next, hold the axe by the handle, first at, say, one foot from the head, then at two feet, then perhaps at three feet, and give blows which seem of equal intensity, and mark the depth. Thus a practical testimony to the value of a handle will be borne by the respective depths.

A few words about the motion of the hands and the handle they grasp; and then a consideration of the curves given to the cutting-edges of axes, adzes, etc.; also to the wedge-like sections of the edges. These will be all that can now be considered.

The motions of the hands on the handle of an axe are similar to those of a workman on that of the sledge-hammer. The handle of a properly-handled axe is curved, that of a sledge-hammer is straight. For present consideration this curvature may be overlooked, although it plays an important part in the using of an axe with success and ease. If the almost unconscious motions of a workman skilled in the use of an axe be observed, it will be noticed that, while the hand farthest from the axe-head grasps the handle at the same or nearly the same part, the other hand, or the one nearest to the head, frequently moves. Let us follow these motions and consider the effect of them. The axe has just been brought down with a blow and entered between the fibres of the wood. In this position it may be regarded as wedged in the wood, held in fact by the pressure of the fibres against the sides of the axe. From this fixity it must be released, and this is usually done by action on or near the head. For this purpose the workman slides his hand along the handle, and, availing himself (if need be) of the oval form of the handle after it has passed through the eye of the metal, he releases the head. The instrument has now to be raised to an elevation; for this purpose his hand remains near to the head, so causing the length of the path of his hand and that of the axe-head to be nearly the same. The effect of this is to require but a minimum of power to be exerted by the muscles in raising the axe; whereas, if the hand had remained near the end of the handle most distant from the head, then the raising of the axe-head would have been done at what is called a mechanical disadvantage. Indeed, if a workman will notice the position of the hand (which does not slide along the handle) before and after the blow has been given, he will find that its travel has been very small indeed. Remembering that the power exerted to raise a body is in the inverse ratio of the spaces passed through by the body, and the point of application of the power, it may thus be obvious how great a strain will be on the muscles if the axe-head be raised by the hands at the opposite extremity of the handle. Reverse the problem. Take the axe-head as raised to such an elevation as to cause the handle to be vertical (we are dealing with ordinary axes, the handles being in the plane of the axe-blade). Now, the left hand is at the extremity of the handle, the right hand is very near to the axe-head—the blow is about to be given. The requirement in this case is that there should be concentrated at the axe-head all the force or power possible; hence to ease the descent would be as injudicious as to intensify the weight of the lift. Consequently, while with the hand nearest to the head (as it is when the axe reaches its highest elevation) the workman momentarily forces forward the axe, availing himself of the leverage now formed by regarding the left hand as the fulcrum of motion, he gives an impulse, and this impelling force is continued until an involuntarily consciousness assures him that the descending speed of the axe is in excess of any velocity that muscular efforts can maintain. To permit gravity to have free play, the workman withdraws the hand nearest to the head, and, sliding it along the handle, brings it close to the left hand, which is at the extremity of the handle; thus the head comes down upon the work with all the energy which a combination of muscular action and gravity can effect. The process is repeated by the right hand sliding along the handle, and releasing as well as raising the head.

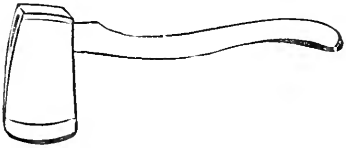

Fig. 6.

The form of the axe-handle deserves notice, differing as it does from that of the sledge-hammer. In the latter it is round or nearly so, in the axe it is oval, the narrow end of the oval being on the side toward the edge of the axe, and, more than this, the longer axis of the oval increases as the handle approaches the head, till at its entrance into the head it may be double what it is at the other extremity. It often has also a projection at the extremity of the handle. The increasing thickness near the head not only gives strength where needed, as the axe is being driven in, but it also supplies that for which our ancestors employed the thongs as illustrated in Figs. 4 and 5. There is, too, this further difference—in a sledge-hammer more or less recoil has to be provided for, and the handle does this; in the axe no recoil ought to take place. The entrance of the axe-edge is, or ought to be, sufficient to retain it, and the whole of the energy resulting from muscular action and gravity should be utilized. The curvature, too, of the handle is in marked contrast with the straight line of the sledge-hammer handle. The object of this curvature is worthy of note. In my hand is an American forester's axe. The handle is very long and curved. If, laying the axe-handle across my finger where the head and handle balance, I place the blade of the axe horizontally, you may notice that the edge does not turn downward; in fact, the centre of gravity of the axe-head is in the horizontal straight-line prolongation of the handle through the place where my finger is. Now, in sledge-hammer work the face is to be brought down flat, i. e., as a rule, in an horizontal plane. Not so with the forester's axe: it has to be brought down at varying obliquities. If, now, the hewer's hand had to be counteracting the influence of gravity, there would be added to him very needless labor; hence the care of a skilled forester in the balance of the axe-head and the curvature of the handle.

We must now consider the form of the cutting-edge as seen in the side of the axe. It is often convex. The line across the face in Fig. 7 indicates the extent of the steel, and the corresponding line in Fig. 8 the bevel of the cleaving edge. It will be noticed that the cutting-edge in each case is curved. The object of this is to prevent not only the jar and damage which might be done by the too sudden stoppage of the rapid motion of the heavy head in separating a group of fibres, but also to facilitate that separation by attacking these fibres in succession. For, assuming that the axe falls square on its work in the direction of the fibres, a convex edge will first separate two fibres, and in so doing will have released a portion of the bond which held adjoining fibres. An edge thus convex, progressing at each side of the convexity which first strikes the wood, facilitates the entrance of successive portions from the middle outward. If the edge had been straight and fallen parallel to itself upon the end of the wood, none of this preliminary preparation would have taken place; on the contrary, in all probability there would have been in some parts a

Fig. 7.

Fig. 8.

progressive condensation of fibres, and to that extent an increase in the difficulty of the work.

The equally-inclined sides of the wedge-form of edge hitherto alone described as belonging to axes, and the equal pressure this form necessarily exerts upon each side if a blow is given in the plane of the axe, suggest what will be the action of an axe if the angle of the wedge is not bisected by the middle line of the metal. Assume that one face only is inclined, and that the plane of the other is continuous to the edge, then let the blow be struck as before. It will be obvious that the plane in the line of the fibres cannot cause any separation of these fibres, but the slope entering the wood will separate the fibres on its own side. Suppose a hatchet sharpened as previously described, and one as now described, are to be applied to the same work—viz., the cutting from a solid block the outside irregularities—say to chop the projecting edges from a square log and to prepare it for the lathe. It may be briefly stated that the hatchet described in the second case would do the work with greater ease to the workman, and with a higher finish, than the ordinary equally-inclined sides of the edge of the common hatchet. Coach-makers have much of this class of hatchet-paring work to do, and the tool they use is shaped as in Fig. 10. The edge is beveled on one side only, and, under where the handle enters the eye, may be noticed a piece rising toward the handle; on this the finger of the workman rests in order to steady the blade in its entrance into the timber in the plane

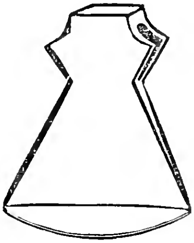
Fig. 9.

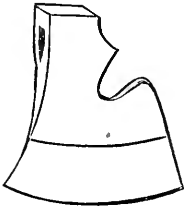
Fig. 10.

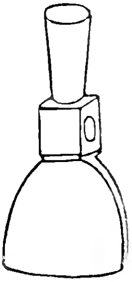
Fig. 11.

of the straight part of the blade, and to counteract the tendency of the wedge-side pressing the hatchet out of its true plane.

ON ADZES.—Those whose business requires the forming of lengths of wood into curved shapes, and who rely upon the adze for the preliminary operation, use an Indian form of adze. In India it is held so near the metal that the workman's hand touches the metal. He accomplishes blows chiefly by acting from the elbow. This very general mode of holding gives a pretty uniform length to the radius of the swing, hence the form of the adze in the plane of the swing is nearly that of the circle described. The angle of the handle and the adze is very much the same as that of the handle of the file-maker's hammer and the head.

THE TWO-HANDED ADZE.—When we look at the adze as used by English wheelwrights or shipwrights, we may well shudder to see how it is handled, especially when the cutting-edge is taken into account. The operation, briefly described, is the following: The workman stands with one foot upon the wood, this foot being in the line of the fibre. He thus assists in steadying (say) the felloe of a wheel. From this felloe much of the wood on which the sole of his shoe rests has to be removed. It will be noticed that the long handle of the adze is curved—the object of this is to permit an efficient blow to be given, and the instrument brought to a stop before the handle strikes any part of the workman's body; in fact, caused to stop by the exhaustion of its impact energy in and among the fibres of wood to be separated. The edge is often so keen as to cut through a horse-hair held at one end and pressed against it.

This instrument is raised by both hands until nearly in an horizontal position, and then not simply allowed to fall, but steadily driven downward until the curved metal, with its broad and sharp edge, enters near to, if not below, the sole of the workman's shoe, separating a large flake of wood from the mass; the handle is rapidly raised, and the blows repeated. This is done with frequency, the workman gradually receding his foot until the end-flakes of wood are separated. It is fearful to contemplate an error of judgment or an unsteady blow. William Tell and the apple on his son's head are, in another form, here repeated.

FIG. 12.

So skilled do men become in thus using the adze, that some will undertake, with any predetermined stroke in a series, to split their shoe-sole in two.

CURVATURE OF ADZE.—Clearly the adze must be sharpened from the inside, and, when the action of it is considered, it is also clear that the curvature of the adze-iron must be circular, or nearly so.

The true curvature of the metal may be approximately deduced from considering the radius of the circle described by the workman's arms, and the handle of the adze.

The edge of the adze is convex (Fig. 12), the projection in the middle being so formed for the same reasons as influenced the curvature of the edge of the axe already alluded to.

The curvature in the blade also serves (though partially) as a fulcrum, for, by slightly thrusting the handle from him, the workman may release such flakes of timber as are over the adze, and yet so slightly adherent as not to require another blow. Thus the adze when applied lever-fashion discharges its duty as the curvature in the claw of a hammer does. Fig. 13 is a gouge-formed adze: a modification of this is used in making wooden spouts, and similar hollow work.

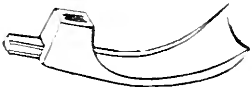

FIG. 13.

Many of the remarks applied to axes and adzes also apply to pick-axes. It may suffice to refer to two forms of this tool; they differ not so much in the operative points as in the size and distribution of the material.

The one used by paviors is long and light, and of large curvature; the other, used by stone-masons and quarrymen, is short-handled and heavy, much material being concentrated in the head. There is also another form of this instrument used on kegs, for the purpose of driving home the wooden wedges; in this form there is no point, the tool is rather that of an elongated hammer, the ends being provided with "panes" of different forms, set off at different angles. Such tools may properly be consigned to the class of hammers.

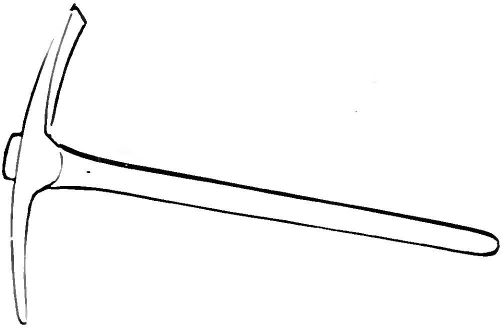

FIG. 14

The pavior's, the mason's, and the quarryman's picks are the three to be very briefly considered. The first is properly a lever, and no more; its pointed end is for entrance between stones, and then the wooden handle and the unemployed elevated arm of the pick are used as two lever-arms at right angles to each other; thus motion can be had in two planes for the varying character of the pavior's work.

Such an employment is never allotted to the stone-mason's pick. The object of this is to remove chippings from stone much as the single-angled edge of an axe or an adze would do with chips from timber. It is, however, pointed and not edged, because stones are not fibrous. The weight of the iron head corresponds exactly with that of a heavy hammer, and, so far as this particular feature is concerned, the considerations in relation to hammers apply.

There are peculiarities in reference to the points of these tools. The whole of the energy of the workmen is expended upon one point (in the carpenter's axe or the wheelwright's adze this energy is distributed over an edge from four to eight inches in length), hence the rapid wear of this point, and the necessity not of frequent grinding, but of frequent reforging and retempering. Any attempt at grinding up these points would be practically unsuccessful, made as these picks usually are, because of the mass of metal required to give that penetration resulting from the sudden stoppage of heavy weights. The ordinary picks are therefore sent to the smith's to be sharpened. For this purpose they must be removed from the handle; and this has suggested forms of eye and handle which might with advantage be used with some other tools.

The axes and adzes hitherto considered have been chiefly regarded as tools for the greatest amount of heavy work to be accomplished by a workman. They are at one extreme of the scale, the other extreme being the removal of such small flakes as to become shavings of varying thickness. In progressing from great to small, the order would be from the axe or adze with its weighted head to a separation of the cutting-edge and its necessary metal, and the weight which must give the blow. Hence, in this descending scale, we reach the chisel, struck by a mallet.—*Journal of the Society of Arts.*

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# SUBTERRANEAN STREAMS IN SOUTH CAROLINA.

By Rev. ROBERT WILSON.

NEITHER the formations nor the phenomena described in this paper are peculiar to South Carolina, and the general subject has been frequently investigated in other limestone regions. The present writer, therefore, desires merely to offer some results of his own observation and experience as a contribution to the scientific literature of the subject.

In that portion of the State which lies between the Santee and the head-waters of the Cooper commences a chain of so-called springs which present some exceedingly interesting features. Before describing them it may be well to note the surroundings. The face of the country is flat, without a single hill worthy the name. The soil is a sandy loam, and, being within the thermal influences exerted by the Gulf Stream along the entire lower coast-line for fifty miles or more inland, is well adapted to the culture of the "long-stapled," "black-seed," or "sea-island" cotton, but yields poor crops of corn, and no pasturage. The lower bank of the river is always covered by "the swamp," with its dense canebrakes and its heavy growth of cypress. The upland is a broad and rich belt, dotted with cotton-plantations, and well wooded with oak, hickory, gum, and similar trees. Winding about through this belt is a high ridge of sandy, barren soil, covered by the long-leaved or turpentine pine and a thick undergrowth of "scrub-oak." It is in the middle or plantation belt that the "springs" occur. In both swamp and pine-land the water is soft, while that of the springs is strongly charged with lime, and, unless boiled and iced, decidedly laxative. Good pure water can usually be obtained, however, within a few hundred yards from "pine-land wells," or "freestone" springs. The country abounds in game, especially the swamps—bear, deer, wild-cats, the gray fox, and other small quadrupeds, with turkeys, partridges, woodcock, snipe, and indeed all birds, common to the latitude. No rocks or bowlders are to be found. The springs occur at irregular intervals over a space of some thirty miles, at least; whether beyond that distance or not I do not know. They are not properly springs, there being no case which I can remember where any bubbling or oozing of the water occurs, nor is there any adequate outlet from any of the basins; a small and shallow stream, or "run," which is soon absorbed by the swampy soil, being the only way of escape for the water, while in some cases, as we shall see, there is absolutely no way for it to escape.

Let us now proceed to examine a few of these basins in detail. The most remarkable of them all is on the "Woodboo" plantation, about forty miles from Charleston. Walking toward a clump of tall cypresses, you suddenly find yourself on the brink of a miniature lake, the ground being firm up to the water's edge. An irregular basin, about fifty yards long by a dozen wide, is hollowed out in the blue limestone-rock which underlies the soil but a few inches from the surface, and this is filled to the brim with slightly opaline yet perfectly clear water. The bottom slopes abruptly from either side to the middle, where it is fully twelve feet deep, and where exists an irregular fissure extending the whole length of the basin, and varying from two to six inches (apparently) in width. The basin swarms with fish of every variety common to the waters of the region, and of every size. Schools of fry keep near the edges, hundreds in number, while in the deeper water may be seen full-grown perch and bream, catfish, black bass, pike, and alewives. Watch the bottom for a while, and you will see these fish issuing from the fissure in the rock, the larger bass (four to eight pounders) never venturing far from it, and darting into it at the least alarm. I well remember a pike nearly three feet long which I have often struck with a fishing-cane, but which I never could capture. The largest fish will not take the hook, on account of the exposure to view; but the smaller bream, perch, and bass, bite with great eagerness, and I have often caught from twenty to sixty in an afternoon, selecting the best fish by sight, and placing the bait at their very mouths. Sometimes the basin is almost empty of fish; an hour afterward enough will be visible to overstock a dozen ponds of equal size. By day eels are rarely visible, and you may stir up all the patches of grass along the bed without discovering one; at night they are frequently caught, the negroes sometimes "gigging" them of the largest size. The temperature of the water is the same winter and summer, about 62°, and the fish bite best in the coldest weather. I have examined the sandy margins at all seasons, and have never seen a fish-bed in this or any other of the springs. They do not breed in them, and indeed could not possibly do so.

From the lower extremity of this large basin proceeds the "run," a shallow, winding stream down which the larger fish could not possibly make their way. Indeed, I once caught a two-pound bass stranded, having essayed the passage and failed. Following this run about five hundred yards, we come suddenly on another basin, circular in form and much smaller than the first. Its greatest diameter is probably not over fifteen feet, while its greatest depth, near the centre, is fully ten. The bottom descends like a huge funnel, but on one side there is a projecting ledge of rock, under which, sloping downward in a direction away from the upper basin, is a hole seemingly about a foot in diameter. Out of this hole bass and pike of the largest size are seen to emerge, while the upper basin is filled with small bream and sunfish, biting readily at angle-worms, and occasionally a large red-bellied perch, a species rarely seen in the basin, will dart from under the rock-ledge and seize the bait. The little stream is lost at this basin, which has no outlet, but is surrounded by a wet, swampy piece of ground. Not far from these basins marl has been extensively dug, and one or two beds of greensand have been found, but I never knew the hard limestone-rock which forms the bottom of the springs to be struck in any of the excavations.

Proceeding now in a northwesterly direction, we find another of these basins on a plantation about two miles off. The ground falls suddenly into a little valley about twelve feet deep and six or seven wide, at the head of which stands a very old oak-tree, growing on the upper level. On the southeast the roots have been exposed by the washing of the clay soil, and immediately under them lies the spring.

This is a basin inclosed by an octagonal brick wall, where, for a century or more, the washing of the plantation and other such matters have been performed. Directly under the oak-tree is a ledge of rock, over which the water is about two feet deep. It grows more shallow toward the "run," where its depth is but a few inches; the entire basin is about thirteen feet by ten. The above-mentioned ledge of rock forms the roof of a cave-like aperture some eighteen inches high by three or four feet wide, into whose dark recesses the eye cannot penetrate, the bottom sloping away in a northwesterly direction under the hill which sustains the old oak. Schools of minnows frequent the shallow part, and hide in the water-grass; stir this grass with a cane or stick, and occasionally you may frighten out a small bream or sunfish, but very few fish of any sort are seen in the shallow basin, and these few refuse the most tempting bait. Now, the proper rock-basin here lies just in front of the cavernous opening, and is some six feet deep, but scarcely four in diameter. Drop your line *there*, and, if all is quiet, in a moment your float will dart diagonally down under the rock, and you may draw out a yellow-bellied perch, a blue bream, or a sun-perch of half a pound weight. Look in, and you will see huge bass lying with their heads only visible at the opening, or flashing their silvery sides as they turn into its unknown recesses. I once detected a pair of white eyes peering from the grass at the mouth of this cavern, and, dropping my bait just in front of them, was astonished at hooking an enormous mud-fish; this fish must have weighed five pounds, and he carried several yards of tackle right into the bowels of the earth, whence it soon emerged *minus* hook and lead. The "run" to this basin is not more than three inches deep anywhere, and sinks entirely into a quaking bog some hundred yards from its source. No fish over an inch long could swim seventy yards from the basin, and there is no communication whatever with any other water.

Leaving the "Pooshee Spring," we now ride a little to the east of north, and, at the distance of about two miles, we reach "Moore's Fountains," the most remarkable of the group. Crossing a little "bay" in the pine-land, you notice under your feet a miniature Natural Bridge, a span of rock about six feet wide covered with earth, and a little hole full of clear water on either side. Walking among the pines about a hundred yards to the right, you reach the "Fountains," six or seven holes in the ground, the largest of which is about five feet by eight, and in general character like the larger basins before described, but much more shallow. All these holes contain large numbers of small perch and bream, which bite readily in the winter, but are hardly worth catching. A little to the right of them used to stand two large twin-pines, and directly between their roots was a hole not more than two feet in diameter, and which you could not detect until you stood on its very edge. (I use the past tense, as the trees may have fallen in the ten years since I stood beside them.) This hole seems to go sheer down into the earth, and I have never been able to sound its depth with the longest fishing-line or rod which I had with me. Setting my float about ten feet deep, however, and "bobbing" into it by hand, I have caught, from between those trees, from thirty to sixty good-sized bream and perch of different species, in the course of two hours. The float would go straight down, as if the fish were descending into the bowels of the earth.

The next spring of which I know the existence is at "The Rocks" plantation, some twelve miles away, and the last of the chain is the famous "Eutaw Springs," where a battle was fought during the Revolution. At the latter place there are two openings, some distance apart, and tradition says that an Indian once dived into one and emerged from the other. I do not know whether fish are caught in these or not. No connection has ever been traced between these springs, or fountains, and the neighboring rivers, either of which—the Santee and the Cooper—is many miles away. Here, then, is the proof of a subterranean stream, or more probably lake, inhabited by fish in immense numbers, and of the same species found in the neighboring waters. These fish have perfect eyes, and differ in no respect from their fellows of the ponds and rivers, except that they invariably present that bright, clean appearance characteristic of fish taken from pure, clear water. They must pass freely through the whole course of the underground caverns, for, were all the open basins put together in one, it would not afford food or breeding-space for one hundredth part of the number found in any one of them, and they must live most of their time in utter darkness, for the little openings at which they appear are few in number and many miles apart. The indications seem to be that this enormous subterranean cave or water-course is hollowed out through a narrow stratum of limestone-rock which winds its way in a southeasterly direction; but it may be of far greater extent. Near Pineville, some ten miles from the nearest spring, and considerably off the course, there is a certain spot in the public road where the sound of the horse's feet is precisely like the noise made in crossing an earth-covered bridge, and tradition tells of treasure buried there in Revolutionary times. The water in this section shows no lime, nor indeed does it anywhere except in the springs themselves. The negroes of the region have invested these springs with a supernatural interest, peopling them with water-spirits known as "Cymbees," resembling in their imaginary characters the Undines and kelpies of the Old World.

# MATHEMATICS IN EVOLUTION.

By GEORGE ILES.

WHILE we know that only Infinite Intelligence could reduce the entire phenomena of the universe to mathematical expression, it affords an observer constant surprise to find primitive laws of order and number recur again and again amid the infinite variety of Nature.

The spectroscope would seem to indicate that the elements of our present chemistry are really very complex structures, yet we find them, when grouped in all sorts of proportions as molecules, capable of crystallizing in forms of perfect geometrical symmetry, often of much simplicity. In botany, where the factors both chemically and mechanically are extremely various, we find simple laws obeyed in the disposition of leaves, flowers, and parts of flowers; a remarkable instance of which occurs in the growth of leaves on spirally-leaved plants. In the first order of them, a leaf is found in $\frac{1}{2}$ the circumference of the stem, and throughout the series the arcs occupied by a leaf are respectively $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, and $\frac{13}{34}$, of a circle, the numerator and denominator of each fraction being those of the two next preceding added together.

In the highest plane of Nature, that of animal forms, the conditions fulfilled are too complex to permit any formulation of lines and angles, but natural history in its first chapters gives us the habitations of the nautilus and other organisms low in the scale of life, which in their beautiful volutes and spirals embody simple geometry. So also does the architecture of our common insects, the bee, wasp, and spider, which, wonderful as it is, must remain less so than the work of the microscopic coral zoöphytes, which, while severally living and building where it is easiest, yet unconsciously coöperate through successive generations to complete a structure of comparatively vast proportions and much symmetrical unity.

These few examples, which might be multiplied indefinitely, may serve as bases for the opinion that complex wholes, acting in many cases like simple ones, may be more easily reducible to mathematical treatment than might at first view be supposed, from the number and variety of ultimate factors concerned in any given problem. Nature would seem to act by but few first principles, which she constantly repeats in her various fields, and which, combined in different ways, yield all her infinite manifestations. The scientific progress of our times is marked by the continual absorption of diverse laws into higher and more general ones; thus the forms of force that used to be thought distinct entities are now proved to be interchangeable, and therefore essentially the same. A minor instance of a like kind occurs in the recent investigation of wave-motion. The old notion was that the particles in water-waves moved up and down in straight lines, but the fact has been demonstrated that they roll in circles having a diameter equal to the amplitude of the wave; this holds of all wave-motion, including light, so that the movements of the planets, as they turn on their axes and circle round the sun, are conveyed to our sight by an ethereal motion of precisely the same kind.

Although mathematical studies find ample illustration in Nature, an exaggerated love of symmetry may be induced by them, causing an enthusiast to pass legitimate bounds in an effort to over-simplify intricate problems; thus Kepler attempted to harmonize the orbits of the five planets with the boundaries of the five regular solids successively contained in each other. Such a vagary, however, could be pardoned in the author of the three immortal laws of astronomy.

In the present stage of knowledge so few of the sciences are exact, that any application of mathematics to the vast and complex processes of evolution is only allowable when the laws considered would be so powerful, did they work in an open field, that, though veiled by many weaker ones, they remain distinctly discernible in the salient features of Nature.

A valid application of this kind is made by Mr. Darwin in his theory of natural selection, where he states the tendency of organisms to multiply according to the law of geometrical progression—a tendency which he shows counts throughout the mazy conflict of forces affecting organic life. The purpose of this paper is to trace some effects of other such laws, in their theoretical simplicity so extremely potent, that their results persist through all practical qualifications, and so, when shown to account for observed facts, may serve as tenable ground for inference and deduction.

In evolution heterogeneity is a constant measure of progress, hence the laws stating the variety of effects producible from given elements have a direct interest and value. These are the laws of combination and permutation. Combinations, mathematically, are groups where the presence and not the position of an element counts for difference—thus B C A and B A C are the same combination but different permutations. As additions are made to the elements, combinations increase in geometrical progression with 2 as constant factor. Thus 2 elements yield 4; 3, 8; 4, 16; until, when we reach 63, the number of elements in chemistry, we find more than nine quintillions of combinations to be possible. This law tends to hold only in cases where the particular position of an element in a group is indifferent, as in the superimposition of colors in light; as in the simple molecules of chemistry, where, for instance, the result is the same, whether $H^2$ unites with O, or O with $H^2$; and as in all merely mechanical mixing of ingredients in manufacture, as pottery, gunpowder, and so on. Such cases are less common in Nature and art than those in which definite positions are points of difference, as we find in the atomic grouping of compound molecules, where the phenomena of isomerism appear; in the order of successive sounds, whether in language or music; and as in the various series in which muscular and nervous forces coördinate in animal movements. In all such cases the multiplication of effects tends to follow a law of even greater increase than that of geometrical progression—namely, the law of permutations.

If A B C be elements given, their permutations in groups of 3 are 6 ($3 \times 2 \times 1$), in groups of 2, 6 more, and adding 3 for the elements taken singly, 15 is obtained as the number of permutations of all kinds. The addition of a new element increases them to 64 ($15 \times 4 + 4$), and so on in a ratio increasing with every additional element, until we find that 10 produce 9,856,900 permutations, and but 1,024 combinations.

These abstract laws are paralleled by the multiplied results which follow in the wake of any important invention or discovery. Forty years ago the main arts of representation were five in number—sculpture, painting, printing, engraving, and lithography. The art of photography, introduced by Daguerre in 1839, and since so beautifully developed, is continually increasing derivative arts. It is applicable to every other main art, and may become an element in new permutative groups of them. It has already given aid to the sculptor, the painter, and the engraver, and in the heliotype and woodburytype exhibits relations with lithography and printing; besides, it has added to human power in many other ways, has made the stereoscope available, bringing the natural beauties and artistic treasures of distant lands vividly near; it has aided astronomy in fixing views of transits and eclipses of brief duration, and in mapping the sun and moon; the physiologist has used it to preserve the evanescent exhibitions of dissection; and in observatories it accurately marks the minute movements of delicate apparatus. It limns the interiors of pyramids, catacombs, caves, and mines, giving incidental help to archæology and geology; and, in regions inaccessible to man, pictures the depths of the sea. It serves in war—and might in peace—to aid the topographer in mapping plans of city and country; in times of siege it has reduced correspondence to microscopic limits for carriage in the only possible way—by birds; and from year to year this wonderful art continues to be applied in new and valuable uses.

The illustration it affords of the manner in which human resources are multiplied by the accession of a new discovery might be repeated, were all the applications and results of the steam-engine, locomotive, or telegraph, traced in their numerous ramifications. So far from these mighty achievements exhausting the conquests possible to man, they are merely centres of new circles of power from which he may successively penetrate into the ever-boundless regions of the unknown.

The late Mr. Mill, at a period of great depression in his early life, found relief in the charms of music, and strangely enough dreaded an exhaustion of it, just as many other people who have not the excuse of morbid ailment think that all the greatest possible discoveries have been made, and that all the finest things in prose and verse have been said. Such notions are denied by the laws which have been stated, as exemplified not only in the diversity and might of modern achievement, but also in the deep relations between the elements of natural action divulged by their very multiplication of effects; the generalizations of this age have never been equaled in scope and force—the persistence of force and the theory of evolution.

As sciences advance, their essential unity becomes more and more evident; methods that at first view would seem utterly unconnected are being constantly found to have a secret and helpful family tie. The comparative value of various types of bridges has been investigated by submitting glass models duly weighted to polarized light, which shows at once the distributions of strain and pressure. A common magnetic needle has been successfully employed in finding weak places in iron and steel axles by its unequal deflection at such points, due to internal heterogeneity in the mass examined. At Paris recently an underground pneumatic tube became obstructed at an unknown point; excavation was correctly guided by the adoption of an acoustic principle; a loud sound was made at the tube's entrance, and the time occupied before the reflected wave returned was carefully noted, from which was inferred the distance traversed by it to and from the obstacle. Many instruments at first made for purely philosophical study have been drafted into the world's practical uses. Applications of the rheostat and Wheatstone's bridge serve to locate the oft-recurring breaks in ocean-cables and telegraph-lines, and have very lately yielded the marvellous duplex and quadruplex telegraphs. The spectroscope, originally directed to the heavens, has now found uses on earth of great value; it detects adulteration, marks defectiveness in drainage, and points out impurities in water-supplies.[1]

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[1] A proposition in pure mathematics may receive elucidation and extension by an illustration taken from optics. In Newton's "Principia," book i., section xii., prop. 70, he proves, in a manner very difficult to follow, that a corpuscle placed within a hollow sphere, if attracted as the square of the distance by all the points in the concave surface, will remain unmoved wherever placed, as the sums of attraction always balance.

This may be made clear not only of a spherical surface, but the closed interior of any surface whatever, provided it has no reëntrant angles, as a pyramid or an obliquely-truncated cone.

For, imagine the corpuscle to be luminous and to be bisected by any plane extended so as to cut the containing hollow surface into two parts, it is evident that equal amounts of light are radiated by each half of the corpuscle on each of the two parts of the surface containing it. Now, these rays diminish in intensity as the square of the distance, and so reciprocally correspond with a force emanating according to the same law from the surface and affecting the corpuscle. Hence, the area of the surface of any hollow body, having no reëntrant angles, varies as the square of its average distance from any point within it.

So that, in the tree of knowledge, as the branches grow in all directions, their offshoots come to touch at innumerable points.

The multiplication of effects may be traced not only in physics, chemistry, and cognate sciences, but also in the chapters of natural history and the facts of human life. The organized faculties of an animal which are distinctly different may be considered—of course, with proper qualification—as elements which may be grouped permutatively in the various actions directed to aid maintenance or promote safety; although, in the case of any particular variety of a species, a vast discrepancy must exist between the theoretical results of the mathematical law and the number of different groupings really made, yet, if the discrepancy is tolerably constant in degree in any two successive cases, the relations between two such cases may be stated by the law with an approximation to truth. Thus if a variety of quadrupeds with, say, four distinct and presumedly averaged powers be taken, at first sight it would seem but one-third better off in the struggle for existence than another variety with three several powers; yet the one may have an advantage over the other as great as four to one, for the variety of actions possible to the former may cover a field four times as great as the others. This aids us in understanding why variations in useful rather than those in useless directions tend strongly to persist. They do so because of the immense exaltation of power that comes with the development of any new faculty, any new means of securing a livelihood or escaping danger; and so great is this exaltation that even minor degrees of development have an appreciable value and tend to become permanent and to increase.

The effects of the laws under consideration also help to make clear why transition periods in organic Nature have been brief as revealed in their infrequent traces in such geological records as we possess.

When new circumstances have demanded the acquisition of new powers, or rather the development of dormant ones, the odds have been overwhelming against such individuals of a race as have been inelastic in the required direction, so that in a comparatively short period all that lived knew the new lesson.

A further corollary which harmonizes with observed facts is that, as species progress, an ever-increasing width of gap would separate kind from kind, and the highest individual of a kind from the next below it. The lowest organisms, monera, have no definite shape; polyps, some grades above them, conform very tolerably to a certain outline; and so on in the scale of life an increasing individuality keeps pace with an increasing divergency, until man and the tree mark the two great summits of Nature in her animal and vegetal forms.

Many able students of the theory of evolution stop short at the chasm which divides the human climax from the allied primates, and hesitate to believe that there can be a common origin for apes and the race which has produced a Beethoven and a Raphael; but a consideration of the laws which have been stated, and which are closely borne out by observation, would lead us to expect just what we find, namely, in the processes of development intermediate links would drop out after comparatively brief existence between planes of life increasingly separated, so that the last difference of power and intelligence would be the greatest of all.

And, furthermore, the same laws make intelligible the vast gulfs we find fixed between our intellectual giants and the rest of mankind, so that they form a small solitary band above us all, leaving a mere understanding of their mighty works the test of our highest powers. A single English dramatist and a single English mathematician have probably equaled in scope and excellence of original work, in their several fields, all the like labors of their countrymen put together.

Two other mathematical laws, abstractedly of great power and generality, may be noticed in the many phases of evolution, namely, those treating of the relations between areas and solids of the same form, varying in size. In like plane figures, boundaries increase directly as like dimensions and areas, as the square; in similar solids, surfaces increase as the square and contents, as the cube of like dimensions. These laws state in an abstract way the economy of aggregation, whether domestic, industrial, social, or political. The farmer profits by them when he takes down costly fences in enlarging his domain; the ship-builder avails himself of them when he models his monster craft which shall carry the cargo of half a dozen small vessels at half the expense; the Broadway architect embodies them in his lofty designs, rivaling in a business structure the height of a common church-steeple, putting two ordinary buildings on one lot of ground.

From the time when animals first noticed that two together were stronger than two singly, the gregarious instinct has been assisted in taking a firm hold on many species from its usefulness in attack and defense; where it is not exhibited, exceptional circumstances prevent: for instance, a spider would have nothing to gain by going into partnership, for it preys on flies much weaker than itself, and no company of spiders, however large, could do battle with a swallow, or a housemaid armed with a broom.

Speaking in a general way, such savage tribes of men as have had the strongest social feeling, and the largest mutual confidence, have, other things equal, had an advantage over less coherent neighbors, and so on, until now modern history deals with national groups fewer than ever before, and becoming fewer still.

In commerce, also, the largest banks, mercantile firms, and factories, grow continually larger by virtue of the less expense attending the management of extensive groups. The costly competition of many small manufactories and merchants is passing away before the more economical methods of a few strong concerns. Coöperation in labor, and in the supply of a community with goods, has succeeded to an encouraging extent in Europe, and in some degree on this continent.

In domestic life, also, the burden of sustaining the usual isolated homes is beginning to be thought grievous and unnecessary. The constant repetition of the same details on a small scale, in cooking, warming, and attendance, is evidently subject to a large discount in cost, and increase of comfort, when a number of families combine to have a single kitchen, heating-furnace, and corps of servants. Many solutions of this problem have been attempted with various success; large houses rented in flats, copied from European models, adorn some of the chief streets of New York and Boston, and hotels on all sorts of systems are to be found in our principal cities, numbering among their patrons thousands of families. It may be reasonably expected that in the near future some plan will be arrived at, and widely accepted, combining the benefits of individual homes with the advantages of association; but, for this result, an improvement in our present crudeness of social feelings must take place. Great is the premium placed on the growth of mutual harmony and confidence, yet how slow that growth is!

A process analogous to aggregation is that of concentration, which marks many of the forms of progress. When a force operates against a lesser one of constant amount, concentration multiplies its efficiency.

If a common furnace's heat is 3,500°, and a temperature of say 3,000° is required to melt iron, then but 500° of 3,500° are available for that purpose; but, when the same quantity of heat is presented at 4,200°, 1,200° of 4,200° may be utilized, an efficiency twice as great as the former. Hence the value of such an invention as the hot-blast, increasing the intensity of flame: the inert and diluting nitrogen is mingled with the oxygen of common air by the feeble force of diffusion; if they could be cheaply separated, it would mightily enhance the value of coal. Steam-engines, as now constructed, rarely yield in work more than a tenth the equivalent of heat applied; the chief waste is in the exhaust-steam, which, although in immense quantity, is of too low a temperature to raise more steam. Any feasible plan of concentration is all that is wanted to make the steam-engine more powerful; its duty has already been nearly doubled by the use of much higher pressures than Watt employed or sanctioned. A pebble on a sea-beach may have been exposed to the sun for ages without perceptible effect, but the focusing of a lens may reduce it to the liquid state in a few moments with no more solar beams than might have otherwise idly fallen upon it in an hour. This same principle also obtains in the operations of trade and business: the expenses of a railroad, steamship, or hotel, are pretty constant, and a certain amount of patronage pays them; beyond this point profits rapidly accumulate, and below it so do losses; small fluctuations produce large results in the balance-sheet.

Successive increments of difference in degree may gradually merge and become exalted into a difference in kind. A number of pendulums might, if unresisted, vibrate in an arc forever, but, if on one of them the movements of the others are suitably concentrated, its arc will gradually increase in amplitude until it becomes a circle.

This principle of concentration appears in organic Nature in the physiological division of labor, and in the adaptation of every organism to some particular environment which may be to it its field and kingdom. Analogy would lead us to suppose that the different duties of the brain are performed by special parts. So directly profitable has the division of labor been found in manufacturing industry, that in many cases it has been pushed to an injurious extreme, for a man is stunted in development when all his powers of mind and body but one remain unexercised. Specialists in art and science discover that their highest excellence can only come with a comprehension of wide principles and study in many various fields.

So far from concentration being invariably useful, diffusion may be a process incident to progress. A lump is soonest leavened by leaven distributed throughout it, crystallization proceeds more swiftly from separate nuclei than from a concrete mass. Analogously, the best, wisest, and most talented men of a people exert a larger influence when scattered through it than if gathered into an over-centralized capital, where they radiate chiefly on each other.

In the laws which have been considered thus briefly, it has appeared that their tendencies are continually progressive; that, while the capital of evolution is being increased, so also is the rate of compound interest by which it accumulates. It is now fitting that some of the causes should be noticed which reduce these tendencies from their theoretical power to the moderate activity we find them really presenting.

A minor and unfavorable sort of natural selection is that made by animals not carnivorous when they have a choice of food; they take the best to be had, and leave the rest to propagate its kind. This residue may be very bad indeed, when the total supply is scanty; in crowded pastures the grazing herds only permit the worst parts of the clover to come to seed, and squirrels always first eat the best nuts stored in their hiding-places, and any surplus that might germinate and grow is commonly of a very poor kind. The acquisition of new powers by an animal is usually accompanied by a gradual and injurious loss of its original ones; neither the omnivorous hog nor the higher primates can number readiness in swimming among their resources, although their inferior ancestry doubtless could. The introduction of machinery is steadily causing us to lose the deftness and dexterity of the old, unaided handicrafts, yet never so much as now were knack and skill of value, for they are indispensable to the designer and inventor in their work. A highly-cultivated citizen of New York, when he penetrates the wilds of the far West, must have an Indian to guide him through prairie and forest, for the red-man's perceptions of the phenomena around him remain keen and almost intuitive.

Modern arts vastly outnumber ancient ones, yet do not include them all; antiquity possessed many, either lost by neglect or by being secret with individuals and perishing with them, or perhaps in the extirpation of small, highly-gifted communities by overwhelming barbarous hordes.

The vast preponderance of mediocrity over exalted talent has always limited the influence of intellectual greatness, and at times even perverted it to confirm the low standard of a community's intelligence instead of raising it. A key in metaphor is always something unlocking or unfolding the hidden—this refers to but half the business of a key—it is also used to bind, lock up, and secrete. History furnishes many examples of an unusual might of mind permitted, by the lack of appreciation for its best work, not only to leave it undone, but induced to acquire power by mystifying difficulties instead of resolving them, and so to retard progress by an exertion of the very capacity that might assist it.

The individuals of a community rise pretty much together, and the voice of circumstances is not so loudly "Be your best," as "Be fit." The limit to the practical value of greatness becomes plain if we imagine Kepler, while making a scientific journey, to be suddenly surrounded by hostile Sioux. We can believe that the world may not know some of its greatest sons, for greatness is known only when allied with the talents of publicity and the circumstances of appreciation.

Truths and suggestions beyond the comprehension of hearers have doubtless often been uttered in vain. Our guides in the path of knowledge must keep within easy distance if they are to be useful. Huyghens, the great Dutch philosopher, clearly propounded the wave-theory of light, but it remained unnoticed in his times, to be rediscovered a century afterward, when the minds of scientific men had been prepared to receive it.

Then, again, the very intensity of appreciation bestowed upon genius may be hurtful, in the diversion of men of some original power from the development of themselves into the army of mere repeaters, imitators, and quoters. Besides, when the leaders of thought and investigation have erred, as at times they inevitably must, the mistaken opinion from the weight of a great name becomes a clog and a barrier. Newton's emission-theory of light delayed the true explanation through many weary years; and zoölogy is still suffering from the belief in catastrophes entertained in the mighty brain of Cuvier. And, further, physiologically, the antagonism of growth and reproduction has left the chiefs of men either childless, as Kant, or continued in a puny race, as Cromwell. Talent is hereditary, but genius scarcely.

Progress is also thwarted by the sub-evolution of evil. In human societies, as mutual trust and confidence advance, they are liable to be rudely checked from time to time as the rewards of the liar and thief temptingly increase. The very perfection of mechanical appliances is used by the burglar and counterfeiter, and only a high degree of educated ingenuity and a world-wide mercantile good faith could have made such a fiend as Thomassen possible. The invention of new machinery, the manufacture of new chemicals, the extensions of mining, and the commingling of increased travel, in their accidents and sometimes in their baneful results in common pursuit, render the tasks of physician and surgeon more difficult than ever before. The complications of modern life are so great and varied, that the moral laws do not possess the direct and simple force they had of old; in the surge and vortex of to-day it takes a keen intellect to separate right from wrong, and many err because their consciences are not reënforced by education for the new exigencies.

Evolution is underlaid, as is all change, by the greater law of the persistence of force, ever holding the even balance through all complexity, maintaining throughout all a just compensation. Every new faculty and enjoyment is earned by its equivalent of work, trouble, or ill; with every addition to power comes an addition to wants, to labor, and the possibilities of pain. As the stores of the mind increase so also do ideals craving satisfaction become higher and wider: ever "on the isthmus of a middle state," man is at once a record of the past and a prophecy of the future; limited by his inheritance to definite acquirement, he yet aspires, by nascent impulses, for such better things as only his posterity can ever possess.

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# EXPERIMENTS ON HYPNOTISM.

By FRANKLIN CHASE CLARKE, M. D.

SOME time ago my attention was called to two articles on "Hypnotism in Animals," in the columns of The Popular Science Monthly,[1] in which I became very deeply interested.

For the sake of those who may have forgotten what the author, Prof. Czermak, said in regard to these very curious phenomena as observed in fowls, I will briefly describe his mode of proceeding, and afterward give the results of my own experiments.

And, first, of the crawfish experiment. If a crawfish is held firmly in one hand, while with the other "passes" are made along the back of the animal from head to lower extremity, the animal will become so quieted as to allow itself to be placed in any position whatever, even the most unnatural, without once stirring. Among people generally

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[1] September and November, 1873.

this has been called "mesmerism" or "magnetism." Prof. Czermak proved that neither magnetism nor mesmerism is active in the production of this phenomenon.

This case is simple enough, that of the fowls is more complex. It has been thought that if "a chalk-line" were drawn the length of a hen's beak, or from eye to eye across the beak, while held upon a flat surface, she would remain perfectly quiet for more or less time when the hands were removed. I think this is commonly believed in our own country. Here, the chalk-line seemed intimately connected with the phenomenon.

Kircher varied the experiment by erasing the chalk-line. He also tied a ribbon around the legs of the fowl, and then removed it; and the hen still remained quiet. According to him the imagination of the fowl plays an important part; and he laid great stress on the acts of "tying" and "chalking."

Prof. Czermak does not attach much importance to Kircher's conclusions, in his first lecture. But, in his second, he seems to believe that the "tying and chalking" exert some slight influence through the imagination. He relies mainly, however, on the "stretching out" of the fowl's neck. Pigeons gave him more trouble in this respect; and this caused him to modify his theory to some extent. He agreed, however, that after a hen had once been subjected to this *neck-stretching* process, she could be caught and placed upon the floor or any other surface, *without* being again subjected to it; that is, hold her firmly until all struggling has ceased, and she can be placed in almost any position without once touching the neck. Here Prof. Czermak stops, and from this point my own experiments begin.

I first repeated many of his experiments on fowls, without using chalk and string, and with as successful results. Afterward I varied the mode of experimenting. Hens, ducks, cats, and canary-birds, have thus all succumbed to this peculiar procedure at my hands, and in every instance *without* my subjecting them once to "neck-stretching," except, of course, when I was repeating his experiments.

My first experiments, since repeated, were made upon some pet canary-birds when I was quite a child, and knew nothing of this phenomenon. I had three of these little birds, one male and two females. These I would often remove from their cage, hold them in my hand until they became quiet, and then place them upon the floor. In this way I would often have all three lying out upon the floor perfectly motionless. As to whether their eyes remained closed or not I have no recollection. The male was very wild, and, if not watched carefully, would fly from the floor.

This experiment I have since practised on a canary, and obtained the same results as I did when I first noticed the peculiarity. Here let me say again that I never touched the head or the neck of the bird.

When quite a lad, and residing in a Western State, I often observed the farmers brought their poultry alive to market, preventing the escape of the fowls by tying their legs together. The fowls, whenever I saw them, were always quiet.

Prof. Czermak thought that the stretching out of the neck of the fowl caused, in some manner, a "slight mechanical extension of certain parts of the brain, . . . . apart from the fear which the animal experiences," etc.[1]

Now, since my last experiments I dispensed entirely with all "neck-stretching." Prof. Czermak's explanations do not tend to throw that light upon the subject which he believed they would; and we must look to Kircher for a fuller explanation of this phenomenon—that of the power of the imagination.

Those parts, then, which it has been said were necessary to touch for the success of the experiment, I have latterly entirely let *alone.*

I usually, after catching my fowl, hold it firmly upon the ground, floor, etc., as the case may be, until all struggling has ceased. Then I remove my hands, making no "passes," nor any more movements than are necessary to take them away from the animal. Now I have the fowl stretched out before me motionless, and breathing deeply; the eyes are generally open. Some hens are more easily subjected to this experiment than others. Tame hens will allow much handling, and are hence never good subjects. A very wild fowl is an excellent animal upon which to make these experiments.

As in the cases instanced by Prof. Czermak, so I find different fowls must be differently treated. Some require to be held a shorter, some a longer time, than others. But this fact is evident, that the animal must be held firmly until perfectly quiet.

It was only the other day, while writing the above, I visited a neighbor's poultry-yard to verify still further my views upon this subject. After catching a huge Brahma cock, which I had great difficulty in holding, as he was very violent, I held him fast until *he* as well as I knew he could not escape, and then took away my hands. He lay just as quiet as though my hands were holding him. But his eyes were *open* and his head was somewhat raised from the ground. In this condition I placed him in his coop, where he remained in a most awkward position upon his side until a hen came along, and seemed to assure him of his liberty.

Thinking that the "stretching out of the neck and bill" had simply the effect of closing the animal's eyes, I held a duck firmly in one hand, and with the other threw my handkerchief over its head. The same phenomena resulted, but they were of shorter duration. I next treated a little bantam pullet in the same way; but, being a tame and gentle little creature, I could do almost anything with her. One singular feature was that, while upon her back, and the handkerchief over her

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[1] *Vide* POPULAR SCIENCE MONTHLY, *loc. cit.*

head, she began to sing. She remained very quiet, but only for a short time.

A gentleman told me of a somewhat similar process he employed in the West, when he had entrapped in the same box several prairie chickens. It being difficult for him to hold more than one chicken at a time, he would take one from the trap, hold it until quiet, shake it a little, and then lay it upon the snow. Sometimes he would have two or three thus lying there with their eyes closed. They would remain in this condition long enough for him to secure the whole catch. But, if one chanced to open its eyes when he was not looking, it would most certainly escape.

The explanation of all this does not seem difficult. In fact, we do not feel obliged to bring forward *mesmerism*, *magnetism*, nor even *hypnotism*, as having anything to do with the phenomena. They result simply from fear, as any one may easily prove for himself: the animal appreciates the power acting on it, and the uselessness of resisting the injury or the supposed injury inflicted. Here, of course, we must allow animals a certain amount of intelligence for such perceptions. After the animal has made resistance, and finds itself incapable of removing the obstacle, it lapses into quietude, to act again only when it supposes the restraint has been removed.

Hence, Kircher, apart from his "ribbons" and "chalk-lines," or "remembrance of chalk-lines and ribbons," is not so far out of the way in believing these phenomena to be due to the power of the animal's imagination. The same thing, under certain circumstances, is observed in man, and every one must be aware of the power the imagination often possesses over him.

In the "charming" of the lower animals by serpents we notice similar phenomena. The *so-called* "charmed animal" cannot move, from the fact that it does not believe it can. It has no power of will to put into operation those muscles necessary to carry it from danger. In other words, it is paralyzed with fear.

The cat playing with the mouse still further illustrates the same principle. The mouse knows he cannot escape, for, at every attempt to move, pussy's paw is put gently upon him, and he is pulled back within her reach. Hence, after a while the mouse does not move at all unless pussy "stirs him up," so to speak, with her paw.

Hence we cannot see anything very wonderful, after all, in these phenomena: they depend wholly and only upon fear, and are but an illustration of the power of the imagination among animals, and add to the evidence daily accumulating of the possession by the lower animals of a certain amount of intelligence.

# ORGANISMS AND THEIR MEDIA.

By H. CHARLTON BASTIAN, M. D., F. R. S.

HEAT and light are physical influences to which even the lowest units of living matter respond, whether their mode of life and nutrition is most akin to that of plants or to that of animals. These influences act on such organisms, either by stimulating, retarding, or otherwise modifying the chemical changes naturally occurring in their interior, and upon the existence of which their life depends. Where the vital processes of the organism are stimulated by these physical agencies, their incidence may, in many instances, become the cause of so-called "spontaneous movements." The term, however, as applied to movements, is a bad one—since all the movements of an organism are alike dependent upon a series of antecedent states of contractile and other tissues. There is some sort of foundation, it is true, for the popular mode of expression. A movement is not said to be "spontaneous" if it follows immediately upon some external impression as a cause; the term is generally applied where the cause of the movement is not distinctly recognizable. In some instances the undetected or unconsidered external cause may be the incidence of a diffused physical agent such as heat, which, by stimulating the vital processes, seems to give rise to spontaneous movements. In other cases so-called "spontaneous" movements are to be referred to internal states or changes, whose origin is even less distinctly traceable, to impressions, it may be, which emanate from some of the internal organs, and thence are transmitted to ganglia in direct relation with some of the organs of locomotion.

Heat mostly acts on organisms upon all sides alike, so that, though it may stimulate their life-processes generally, and, in some instances, give rise to movements, these movements are not determined in one, more than in another, direction. Thus, while heat stimulates the "to-and-fro" or the gyratory movements of bacteria, and also renders more striking and rapid those changes of form which all amœboid organisms are apt to display, the movements evoked are random, and apparently devoid of all purpose.

It is not altogether similar, however, with the influence of light. This agent almost always, and necessarily, falls more on one side than on another; and consequently it often suffices to induce movements to be made in definite directions, by the lower forms of life, just as it causes definite and responsive movements to be executed by certain parts of higher plants, which come fully under its influence. In each case the movement, or altered position, is due to some nutritive change; that is, to some alteration, whatever its nature, in the activity of the life-processes taking place in the part impressed by the light. So that, whether we have to do with the movement of a sunflower, or with the locomotions of minute living units, the essential mode of production of the movement is probably similar. Of the actual locomotions of minute living units under the influence of light many instances might be cited; it will suffice, however, to mention the fact that any green zoöspores which may have been uniformly diffused through the water are very apt, when the vessel containing them is placed near a window, to collect on the surface of the water at the part where most light falls upon them. Minute animal organisms are, however, often affected quite differently by this agent. They are frequently caused to move away from, rather than toward, its source; so that the creatures thus impressed "seek" the shade rather than the glare of sunlight.

The action of such influences and the production of such movements form the beginnings or substrata, as it were, of other phenomena with which we are now more particularly concerned. The unilateral influence of light and the movements to or from its source to which it may give rise afford a connecting link between diffused causes like heat, which, by affecting the general activity of the vital processes in the organisms, may lead to purely random movements, and those more localized influences now to be considered, to which the various definite or responsive movements of organisms are attributable.

The first, because it is the simplest, of these localized influences to be considered is a shock or mechanical impact of some kind, falling upon the external surface of the organism. This is the primordial or most general of all the modes by which the surface of an organism is impressible, and its sensitivity to such stimuli is both in the stage of impression and the stage of reaction closely akin to the general organic irritability of protoplasm — which, indeed, unquestionably constitutes its starting-point. This mode of impression, moreover, is one which tends to establish a correspondence between the organism and the most common events or properties of the medium in which it lives and moves. It is consequently the mode of impressibility most extensively called into play among all the lower forms of animal life. And although the whole surface of an organism, or the greater part of it, in one of the simple animals to which we are referring, may be more or less impressible to shocks or impacts from contact with surrounding bodies, it often happens that such impressions more frequently fall upon, and are more readily received by, certain appendages situated at the anterior extremity of the animal, in close proximity to the mouth. Such specialized parts or tactile appendages are known as papillæ, setæ, tentacles, antennæ, or palpi, according to the forms which they assume in different animals.

Why such organs are developed so frequently at the anterior extremity of the animal, and in the neighborhood of the mouth rather than on other parts of the body, is not difficult to explain. Whatever the mode by which they are evoked or called into being (and the most opposite views may be entertained upon this subject), it seems obvious that, if organs of this kind are to be present at all, they should occur in situations where they might be put to most use. In an animal accustomed to active locomotions, the mouth is, with only a very few exceptions, situated on that part of the body which is habitually directed forward. The anterior extremity thus comes to be the part of the body which is brought most into converse with its environment; and, of the diverse objects impinging against it, or against which it impinges, some are of a nature to serve the organism as food, and some are not. A higher degree of impressibility springs up, therefore, in this situation, where the parts are necessarily exercised so largely with impressions corresponding with food and with others having an opposite relation. It should not surprise us, therefore, to find among the lower animals that the most specialized tactile organs are found in the immediate neighborhood of the mouth. Such organs may be, and are in fact, not unfrequently both tactile and prehensile; though this is more especially the case in sedentary forms of life, like the hydra, the sea-anemone, or some of the tentaculated worms. The tentaculæ of the latter animals would seem to be possessed of an extremely high degree of impressibility, if we are to judge by the report of one who devoted much attention to the study of this class of organisms—the late Dr. Williams, of Swansea. He says: "It is not easy, for those who have never enjoyed the spectacle of the 'feat of touch' performed by the tentaculated worms, to estimate adequately the extreme acuteness of the sensibility which resides at the extremities of the living threads with which the head and sides of the body are garnished. They select, reject, move toward, and recede from, minute external objects with all the precision of microscopic animals gifted with the surest eagle-sight."

But it often happens that the solid bodies serving as food are in a measure soluble, so that, in animal organisms comparatively low in the scale of complexity, some of the tactile structures within or around the mouth may undergo a further specialization by which they become able to discriminate and respond to impressions of a slightly different nature. These parts become sensitive to a more refined kind of contact, such as may be yielded by certain dissolved elements of the food substance, whose local action may be attended by some slight chemical change in the tissue of the organ. Impressions are thus produced whereby the "sapidity" or flavor of bodies is appreciated, and such impressions gradually become associated with definite related movements.

No distinct organ of "taste" or specialized gustatory surface is known to occur among invertebrate animals, except in insects and in such higher mollusca as gasteropods and cephalopods; although such a mode of impressibility does, doubtless, exist in many other of the lower forms of life. Impressions of the two orders already referred to—more or less distinct from one another—are those by which alone multitudes of the lowest forms of animal life, such as polyps, medusæ and various kinds of worms, appear to hold converse with the outside world. Touches and tastes are the names which *we* apply to the subjective effects of such impressions; and, though it is impossible at present wholly to ignore this point of view, or to use language which is not colored by it, I do not now wish to say anything with regard to the nature or intensity of the feelings that may be associated with corresponding impressions in the lower animals. The reader must for the present look rather to the objective effects of these impressions, and in so doing he will learn that these become organically associated with a nervous mechanism by whose intermediation they are able to evoke distinctive movements of a responsive nature.

Seeing, however, that tactile and gustatory impressions can only be made by actual contact of external bodies with the specialized parts of an organism, such impressions are not of a kind to excite movements in quest of food; although they may lead to correlated movements of parts adjacent to those which are touched, as when all the tentacles of a sea-anemone close round a body that has come into contact with some one of them. This effect is due to a radiation of the primitive stimulus, and we may see in such a set of actions only a more rapid and slightly more complex result than is known to follow the irritation of one of the peripheral tentacles on the leaf of a sun-dew. In the latter case the bending of the tentacle actually irritated is slowly followed by the bending of others under the influence of an internally diffused stimulus.

Movements in actual quest of food may, however, be excited in other animal organisms by impressions which suffice to bring them into relation with more or less distant bodies. The way is paved for this result when some portion of the anterior and upper surface of the animal, in which aggregations of pigment occur, becomes more than usually sensitive to light. A dark body passing in front of such a region gives rise to certain molecular changes therein, and these molecular changes differing among themselves become capable of exciting distinctive impressions in the organism which it gradually becomes attuned to discriminate. The power of discrimination in this, as in all other cases, is indicated by the organism's capability of responding to impressions by definite muscular movements—as when the oyster, with the valves of its shell apart, instantly closes them if a shadow is projected over certain sensitive pigment-specks or so-called "eyes" at the edge of its mantle.

This beginning of visual impressions truly enough shows itself as a merely exalted appreciation of tactile impressions; and, inasmuch as such an appreciation of the presence of near bodies would in so many instances be quickly followed by a more gross mechanical contact, the rudimentary visual impression is, as Spencer says, a kind of "anticipatory touch." From this simple beginning, in which bodies only slightly separated from the impressible foci excite certain general or only vaguely specialized impressions corresponding to light and shade therein, the organs of sight and their impressibility gradually become more and more elaborate. To rudimentary aggregations of pigment transparent media are added, which condense the light on these impressible patches, and these media in other organisms are sufficiently like a lens to be adequate to form a definite image of an external body on the layer of pigment, which, on its other side, is in contact with a nerve-expansion communicating with a contiguous ganglion. Numerous simple structures of this kind may exist apart from one another, as in many bivalve mollusks, or they may be far more numerous and closely aggregated so as to form such compound eyes as are met with in crustaceans and in insects. Or individual ocelli may be perfected, as in spiders, or lower crustacea, though most notably of all among the cuttle-fish tribe in which two movable eyes are met with, whose organization is just as perfect as that of the eyes of fishes.

The difference in degree and range of sensitiveness existing between the simple "eye-specks" of some of the lower worms and the elaborate organs existing in the highest insects and mollusks is enormous. The range and keenness of vision become progressively extended, so that creatures with more perfect eyes are capable of receiving and appreciating impressions from objects more and more distant, and the various actions which become established in response to impressions habitually made upon such sensitive surfaces increase enormously in number, variety, and complexity. The relation existing between the keenness of the sense of sight and the powers of locomotion of insects has long been recognized by naturalists. Prof. Owen, for instance, thus alludes to it: "The high degree in which the power of discerning distant objects is enjoyed by the flying insects corresponds with their great power of traversing space. The few exceptional cases of blind insects are all apterous, and often peculiar to the female sex, as in the glow-worm, cochineal-insect, and parasitic stylops."

The various actions of insects and of invertebrate animals generally are, however, found to be easily capable of classification. They are, in the main, subservient to the pursuit and capture of prey, to the avoidance of enemies, to the union of the sexes, or to the care of their young. To such ends are their various motions, whether occasional or habitual, more or less directly related. Nothing is here said, however, as to the extent to which such ends are realized by the animals themselves.

In vision, as I have said, we have to do with a refinement of the sense of touch, whereby the animal becomes sensible of impressions produced by "waves" of light emanating from a distance, and is thus brought into mediate contact with certain distant objects. A refinement of the organs of taste may also occur whereby bodies possessing sapid qualities are capable of impressing organisms still at a distance. Just as vision, in fact, is, in its most elementary phases, a sort of "anticipatory touch," so is smell a kind of anticipatory taste. Yet the two cases are not altogether similar. In vision, the contact—if it may be so termed—with the distant body is mediate, through the intervention of ethereal undulations; while in smell we have to do with a case of immediate contact, not with the distant body itself of course, but with extremely minute particles which it gives off on all sides. An "emission" theory serves to explain the diffusion of odors, though it will not hold for the diffusion of light. From what I have said it may be inferred that, as regards the delicacy of their respective physical causes, the sense of smell occupies an intermediate position between taste and sight.

It is regarded as a matter of certainty by naturalists that such creatures as spiders, crustacea, insects, and the higher mollusks, are capable of being impressed in some way by odors, and that their actions are to a certain extent regulated by such impressions. We have, however, no definite knowledge concerning the parts of the surface which in these, and perhaps in still lower organisms, are attuned to receive such influences. Although a rudimentary sense of smell seems unquestionably to be possessed by such aquatic forms of the invertebrata as crustacea and the higher mollusks, it is, perhaps, a sense-endowment which generally exists in a more developed and more varied form among air-breathing animals. In whatever forms of life it may be met with, however, the sense of smell seems to be very largely indeed related to the detection and capture of food; so, that, in these relations, it comes to the aid of the already-existing senses of sight, touch, and taste, though it has the peculiarity of being scarcely otherwise called into activity among the invertebrata.

Although we have no positive knowledge concerning the situation of the organs of smell among invertebrate animals, there is good reason for believing that in crustacea they are to be found at the base of the antennules; that in cephalopods they are represented by two little fossæ in the neighborhood of the eyes; and that in insects a power of appreciating odors is possibly possessed either by the antennæ themselves, or by a pair of fossæ near their bases. Another cephalic organ has also been referred to as possibly endowed with a power of being impressed by odors. Thus Owen says: "The application, by the common house-fly, of the sheath of its proboscis to particles of solid or liquid food, before it imbibes them, is an action closely analogous to the scenting of food by the nose in higher animals; and, as it is by the odorous qualities, much more than by the form of the surface, that we judge of the fitness of substances for food, it is more reasonable to conclude that, in this well-known action of our commonest insect, it is scenting, not feeling, the drop of milk or grain of sugar."

Looking to the importance of this endowment in reference to the perception of food, and also looking to the situation of the organs of smell in all the vertebrate animals, there is good reason for believing that any similar organs of sense which may exist among invertebrate organisms would be found in close proximity to the mouth, so as to permit of that joint or associated activity between the sense of taste and the sense of smell which is met with in all higher forms of life.

As already pointed out, there are also obvious reasons why the principal specialized tactile organs that may present themselves in lower animals should be found in the neighborhood of the mouth; and for similar reasons, if for no other, the anterior extremity of the body, or the upper surface near this anterior extremity, is the site in which visual organs might be used with most advantage by their possessor. To an active animal, visual organs would not only be more useful at the anterior extremity of the body than elsewhere in relation to its food-taking movements, but also in reference to all other uses to which such appendages may be applied during active locomotions from place to place. To this situation of the eyes only two or three exceptions are met with among animals endowed with powers of locomotion, and these deviations are explicable by reference to the habits and modes of life of the organisms in question.[1]

The part of the body bearing the mouth, and the various sensory organs already named, is familiar to all as the "head" of the animal; and it is owing to the fact of the clustering of sense-organs on this part of the body that the head contains internally a number of nerve-ganglia in connection therewith. This aggregate mass of ganglia constitutes the brain of the invertebrate animals, which, as we shall find, differs much in different classes of animals, not only in disposition and in size, but also in respect to the relative proportion of its component parts. The size of the respective ganglia, indeed, necessarily varies in accordance with the relative importance and complexity of the several sense-endowments already mentioned—those of touch, taste, smell, and vision. The ganglia thus constituting the brain of invertebrate animals are not only connected with their own particular external organs, but, in addition, we find the several ganglia of the two sides brought into relation among themselves and with their fel-

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[1] In some spiders the ocelli are situated rather far back on each side of the cephalothorax, but, as Siebold says: "The disposition and the direction of the organs are in relation with the mode of life of these animals, some of which wait for their prey hidden in chinks of a wall within silken tubes which they have constructed, while others hold themselves motionless in the centre of their webs, or wander from side to side, a mode of life which obliges them to look in all directions" ("Manuel d'Anatomie comparative," tome i., p. 308). According to Prof. Rolleston also in the crustacean genera *Euphausia* and *Thysanopoda*: "Eyes may be, contrary to the otherwise invariable rule in *Arthropoda*, found elsewhere than upon the head" ("Forms of Animal Life," p. cxxi.).

lows by means of connecting fibres, while they are also more distantly united with other nerve-ganglia in different parts of the body by means of commissural fibres.

But another special sense-endowment remains to be referred to. This has to do with the organism's power of appreciating sounds or "auditory" expressions—a power which is, however, probably possessed in only a low degree by most invertebrate animals; since, even in the most perfect form of the organ of hearing among them we have to do with a very rudimentary structure. In this respect there is a great difference between the sense of sight and the sense of hearing. While the eye of the cuttle-fish attains a degree of elaboration that does not fall so very far short of the most perfect form which it displays among vertebrate animals, the organ of hearing, as a mere organ, in all forms of the invertebrata is remarkable for its simplicity, and remains notably inferior to the highest type attained by this sensorial apparatus—which, with its nerve-connections, becomes so enormously developed in many mammals and in man.

Like the sense of sight and the sense of smell, that of hearing, even in its simplest grades, serves to bring the organism into relation with more or less distant bodies, so long as they are sufficiently sonorous to transmit the so-called "sound" vibrations through water or air to the sensitive organs which become attuned to receive such impressions.

An auditory organ does not seem to be present at all—certainly none has as yet been detected or inferred to exist—in many of the lower forms of life; while in other animals, though inferred to exist, it remains as yet unrecognized. This is the case, for instance, with the majority of crustacea, spiders, and insects. Judging from the instances in which an organ of hearing has been detected in mollusks, and in a very few representatives of the classes above named, it seems (however novel the information may be to many readers) that it is an organ of special sense which is not habitually, or even usually, found in the head, and in direct relation with one of the ganglia composing the brain. Further remarks, however, on this subject must be deferred until a brief description has been given of the nature and distribution of the nervous system in some of the principal groups of invertebrate animals.

These, then, are the commonly-received modes by which organisms are impressed from without, and by which they attune themselves to the conditions and actions in their medium. It was recognized by Democritus, and other ancient writers, that they are all of them derivatives, or more specialized modes of a primordial common sensibility, such as is possessed by the entire outer surface of the organism. Touch, taste, smell, vision, and hearing, are sense-endowments, having their origin in organs formed by a gradual differentiation of certain portions of the external or surface layer of the body—that is, of the part in which common sensibility is most frequently called into play. And just as this common sensibility is a crude or general sense of touch, so are the several special senses only more or less highly-refined modes of the same sense-endowment. In the case of special tactile organs, of organs of taste and organs of smell, the several contacts between the animal and the body which impresses it, though differing in their delicacy or refinement, are still immediate; while in the case of the organs of hearing and the organs of vision the contact between the sensitive surfaces and the impressing body is mediate, by the intervention in the one case of vibrations transmitted through water or air, and, in the other, of vibrations from the often far-distant luminous body, through an intermediate and all-pervading ether.

The movements of locomotion, or of parts of the organism which become established in correspondence with these various impressions, slowly increase in number, definiteness, and complexity. Such responsive movements, however, are found, as a general rule, to have the effect of prolonging the action of any influences which previous individual or race experiences have proved to be favorable to the life and well-being of the organism; and, on the other hand, of cutting short or avoiding influences which past individual or race experiences have proved to be contrary to its general well-being. The capture and swallowing of food are ends to which a very large proportion indeed of the definite motions of most of the lower organisms are directed; and this direction of their energies is only a special case to be included under the rule above indicated; just as efforts to escape from predatory neighbors are other, though opposite, instances of the same rule.

In addition to the various modes of impressibility by external influence which we have hitherto been considering, there are certain internal modes of impressibility due to changes in the condition of internal parts of the organism. These are commonly spoken of as divisible into two categories: 1. The impressions derivable from, or in some way attendant upon, the contractions of muscles; and, 2. Impressions emanating from one or other of the various sets of internal organs, such as the alimentary canal and its appendages, the respiratory organs, the genital organs, or other internal parts.

With the first set of impressions we have at present nothing to do. They differ altogether from others, whether of external or internal origin, by the fact that they follow or accompany movements whose intensity they are supposed to measure, and do not themselves lead to movements. Granting that such impressions may have a real existence, it is obvious we can know nothing about them among invertebrate animals, if they have only a subjective existence, and do not cause an efflux of molecular movements along outgoing nerve-fibres.

The second category of internal impressions—those emanating from the viscera—are undoubtedly very important in relation to animal life generally. In part they have the effect of causing contractions of related muscular portions of the viscera—as when the presence of food in certain portions of the alimentary canal excites impressions, followed by contraction whereby the food is propelled farther on. In part, however, they act upon the principal nerve-ganglia—those constituting the brain—and thus excite the external sense-organs with which they are connected to a higher order of activity. Visceral impressions may cause an animal eagerly to pursue food, or to be alert in discovering its mate; so that in these, and in many other instances, internal impressions, reaching the cerebral ganglia, would seem to excite a higher receptivity to certain kinds of external impressions and a corresponding readiness to respond on the part of the moving organs whose activity is related to such external impressions.

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# SCIENCE AND THE LOGICIANS.

By DAVID BOYD, A.M.

UNDER the above heading may be comprehended the most of what we are desirous of saying in review of the article entitled "Science and Religion," by Dr. Charles F. Deems, in THE POPULAR SCIENCE MONTHLY for February.

We first run counter to the author upon the definition of science taken from Sir William Hamilton's "Logic." Says he: "We can all afford to agree upon the definition rendered by the only man who has been found in twenty-two centuries to add anything important to the imperial science of logic. Sir William Hamilton defines science as a complement of cognitions having in point of form the character of logical perfection, in point of matter the character of real truth."

In the first place, Hamilton is not the only man since Aristotle that has been found to add anything important to logic. There has been a whole department, and by far the most valuable department of that science, brought into existence during the last three hundred years. We have reference to inductive logic, or scientific method. Hamilton had nothing to do with the creation of this department. His additions are wholly confined to the barren field of *formal* logic. The other department is the result of the joint labors of Bacon, Galileo, Newton, Herschel (John), Mill, Bain, and Jevons.

Hamilton's additions to formal logic consist chiefly in what is known as the quantification of the predicate, and the moods and figures consequent upon this. There is much difference of opinion as to the value of these additions. Mill and Bain affirm that by the quantification of the predicate no new or distinct meaning is conveyed, nor is there even a more intelligent rendering of an old meaning. In our own opinion the distinction between the comprehension and the extension of propositions is important; but it is paraded with too much ostentation, and treated with too much prolixity. Hamilton's great virtue is his clearness of statement and exhaustiveness of treatment. His method is admirable. Sometimes, however, there is too much display of his own erudition.

But even in the domain of formal logic Hamilton is not the only one that has within the present century made important additions. Prominent among these is De Morgan. Especially valuable are his discussions upon the different values of the logical copula. Prof. Boole has also made important additions to the syllogism, and has most ably supported the theory of the common ground occupied by logic and the mathematics. Prof. Bain also, in pure logic, has made a most important generalization. Hamilton's three laws of thought, namely, identity, non-contradiction, and excluded middle, he has reduced to the single law or canon of consistency.

So much for the assertion that Hamilton was the only man in twenty-two centuries to make any important additions to the imperial science of logic. Like enough the doctor would exclude scientific method from the *imperial science.* Perhaps he regards formal logic alone fit to wear the purple. But even here we see that there can be no such claim set up. If, however, he could claim this distinction, it would afford no reason for receiving his definition of science without question. That should stand or fall wholly upon its own merits. The greatest of men are not without personal biases. It is well known that Hamilton had a metaphysical bias. In his work on metaphysics the first three lectures are occupied in attempting to prove the superiority of mental science over natural science. He quotes with much approval this ancient declaration, "On earth there is nothing great but man, in man there is nothing great but mind." This being his known bias, before examining the definition, an investigator of Nature, a believer in scientific method, might have thought that it was by no means certain that he "could afford" to take it simply on his authority. However, when we come to the definition itself, the *matter* of it is well enough. But we have the temerity to suggest that its *form* might be improved without changing the substance. It is too pedantic and prolix. It is not in a shape easily to be remembered. We would render it thus: Science is *real knowledge logically classified.* But, as Bain remarks, positive definition is not thorough enough. As he says in his second canon on definition, it is needful to assemble for comparison the particulars of the contrasting or opposed notion. We can never know distinctly what a notion is until we contrast it with its opposite. Knowing is discriminating. What is not science? What is the other notion that lies side by side with it—in contrast, but contained under the same genus? Now, if we define science simply as knowledge or "complement of cognitions," it is contrasted with feeling or emotion. Its correlatives are productions designed to please, such as poetry, painting, or the fine arts generally.

If religion be regarded as proceeding wholly from the emotional nature, it may be contrasted with science and classed among æsthetic conceptions. But narrowing the definition further by qualifying knowledge by the terms "logically classified," we then have science as contrasted with or opposed to particular knowledge, or knowledge imperfectly classified. Qualifying further by placing the word *real* before knowledge, we have it contrasted with error or not genuine knowledge. By reading Hamilton, it will be seen that error is his antithesis to his *real* truth in the definition. But hypotheses are not error, since they are not held as truth. The distinguishing character of error is that, while false in fact, is is supposed to be true completely. Hypotheses are neither genuine truth nor errors, so long as they are held merely as such. They lie upon the border-lands of truth and error, and Hamilton's definition cannot banish them completely from the domain of science. They are properly allowed to hover around its borders. But we totally disagree with Dr. Deems as to the value of these "guesses" at truth. Says he, "A professor of religion has just as much right to guess as a professor of science, and the latter no more right than the former, though he may have more skill." Now, as to the right, there can be no dispute, but, as to the value of the guesses, this better *skill* makes all the difference in the world. Prof. Huxley is right in his estimate of guesses. Says he, "Do not allow yourself to be misled by the common notion that an hypothesis is untrustworthy because it is an hypothesis. What more have we to guide us in nine-tenths of the most important affairs of daily life than hypotheses, and often very ill-based ones? So then in science, where the evidence of an hypothesis is subjected to the most rigid examination, we may rightly pursue the same course. You may have hypotheses and hypotheses. A man may say, if he like, that the moon is made of green cheese; that is an hypothesis. But another man, who has devoted a great deal of time and attention to the subject, and availed himself of the most powerful telescopes, and the results of the observations of others, declares that it is probably composed of materials very similar to those of which the earth is made up; and this also is an hypothesis." You perceive that it makes a good deal of difference both as to who guesses and as to what is guessed. Indeed, so many scientific hypotheses have been verified in the face of the opposing theological hypotheses, that there begins to be a strong presumption in their favor before verification. Nor is it strange that we should be led to regard them as highly probable. The investigator of Nature, familiar with her processes and her laws, founds these guesses upon broad and deep analogies.

But we have only to follow the reverend doctor a few pages, until we find that hypotheses, so far from being extra-scientific, wholly make up our science. He mounts Hamilton's definition for the purpose of trampling upon scientific hypotheses. But, in his zeal for narrowing the sphere of science, he arrives at the remarkable conclusion that "all science is purely a classification of probabilities." He has at length kicked the definition completely from under him, and remounted a platform entirely composed of hypotheses. He, however, is careful not to say, "It is certain that there are no certainties." Still he leaves us wholly in the dark as to where may be found those "very few certainties" which it appears to him God has seen fit to show us, "more for the purpose of furnishing the idea than for any practical purpose." The God of the modern divine has still about him a touch of the jealousy of the Zeus of Æschylus. He would have chained to the rocks the modern seeker after hidden knowledge, the invader of his own domain of certainties.

We say that we are left completely in the dark as to where are to be found those few certainties which God has seen fit to show us as specimens. We are assured that they are not to be found in science. This is only classified probabilities. The "imperial science of logic" has been demolished with the rest. We wonder whether it is because science embraces only *real truth* that it is uncertain or probable, or is it owing to its methodical logical arrangement that it has acquired this character? He should remember that most people have faculties called memories, that last them through several pages of reading, and that there is a chance for mediate or remote contradictions to be detected.

Again, in his zeal to prove that all science and religion stand upon the common basis of faith, he overleaps himself, and gives us as the results of his logic, "*Ex nihilo geometria fit.*" So I suppose we may be allowed to say likewise, "*Ex nihilo religio fit.*" Is that what he started out to prove? No, it was only this very sensible proposition, that "we can acquire no knowledge by our logical understanding without faith in the laws of mental operations." This simply amounts to saying that we cannot consistently believe in the products of thinking except we believe in faculties of thinking. We suppose that no one doubts that. But believing that by no means involves the assumption that science or knowledge rests upon the same basis as religious faith. It is a very different thing to believe in our own experiences, feelings, sensations, observations, comparisons, memories, representations, etc., and to believe in certain fundamental religious dogmas, as, for example, "God is an infinite person." God is three infinite persons. The second of these three infinite persons, which all make one infinite person, is now sitting in heaven upon a throne on the right hand of the first infinite person, neither of which has any parts, but all three make one indivisible unity. Most men will continue to think that the above propositions differ very much from the two fundamental axioms of mathematics, "Equals added to equals and the sums are equal; and two things each equal to a third are equal each to each." In denying these, we must deny the laws of thought, the powers of the mind in distinguishing a thing from what it is not, or from that which it stands in contrast with, or in opposition to. All the other axioms of geometry, as Bain has shown, are either verbal propositions or can be derived from these, since subtraction is implicated in addition, multiplication derived from addition, and division implicated in multiplication.

The absurd conclusion at which the doctor arrives, namely, "*Ex nihilo geometria fit*," ought to show him that to begin with a metaphysical point was hardly the proper way to build up the science of geometry. Of course, it being nothing, the geometry that he constructed out of it, no matter how many intermediate propositions intervened, must be nothing. Suppose we try the analytic method of arriving at definitions. But first we are compelled to controvert the assertion that it is necessary to believe the three following propositions, or there can be no geometry, namely, that "space is infinite in extent, that it is infinitely divisible, and that it is infinitely continuous."

Now, I deny that geometry has anything to do with infinity; indeed, the doctor, before he gets through, says even more than this. "Science," says he, "has the finite for its domain, religion the infinite." What we have to do with in geometry is simply the relations of the *attributes* or *propria* of *definite extension.* But as *definite* extension has for its correlative *indefinite* extension, we need to understand it in a sort of general way. Experience furnishes us with the mutually-implicated notions of the contained and the containing, the bounded and the bounding. We cannot separate them completely in thought. The assertion of the one implicates the other. What lies without any extension is space—indefinite space. Simply that it is outside of our particular part of space is all that we have to do with it: whether it is infinite or not is none of the business of the geometrician. Indefinite extension, or the notion of space in general, is very different from the notion, if there be such a one, the words infinite space would connote. Indefinite space is comprehensible in the only sense that it needs to be comprehended, namely, as the correlative of extension or definite space.

This brings us to the genesis of the definitions of geometry. Experience makes us at first acquainted with extended bodies. This acquaintance goes no further than a knowledge of their attributes, or *propria.* All these properties come into the mind as a confused aggregate; it is not clearly perceived as a whole made up of distinct parts. The relation of part to part is perceived only in a vague and general manner. The work of the geometrician is to analyze these parts, and to establish their exact relations. He compares, adds, subtracts, multiplies, divides. In order to communicate his knowledge of the relation of parts, he must use words; these words he must define, if their meaning is not obvious to the one instructed. But if the property is of a primary nature, and given in the experience of every one, there is no need of definition, and indeed no rational definition can be given. This is true alike of the notions, extension, surface, line, and point. Each of these is as much a *datum* of simple experience as the notion of white or blue; and it is just as absurd to attempt to define the one class of concepts as the other. They may be, however, brought out a little more closely by contrasting the correlatives in the manner that we have attempted with extension and indefinite space. Thus surface may be contrasted with the solid volume, or definite space, of which it forms the boundary; line with surface, of which it in turn is the boundary; and, lastly, point with line, of which it is the termination or the where of separation. It is not true that the existence of forms depends upon the motions of points. Forms are given in experience through sensation. A point is the ultimate step in the analysis of boundaries. It is sheer nonsense to attempt to construct lines out of points, surfaces out of lines, and volumes out of surfaces. All that it is necessary to say further upon this subject is, that the differentiæ of the higher mathematics are not nothings, but quantities the least conceivable. The least conceivable portion of a line is not a point; the least conceivable portion of a surface is not a line; the least conceivable portion of a volume is not a surface, for the simple reason that no portion of a thing can be its boundary.

Now, in conclusion, we say that geometry rests upon no affirmations in respect to the infinite, but, on the contrary, it is wholly occupied about the relations of the finite in space. We have the assurance from the doctor that the finite is the sphere of every science, while the sphere of religion is the infinite. This certainly would cast theology out of the sphere of science, for the doctor has laid down as one of its fundamental concepts, "God is an infinite person." Sir William Hamilton's definition, in its very first clause, also excludes theology from science, if we take himself as authority for the meaning of the term cognition. Every cognition is simply a perception of *relation.* The infinite and absolute—equal God—are not thinkable. Hence theology can have no "complement of cognition" out of which to classify a science.

In another place we find that the cry of conflict has its origin in confounding theology with religion. "Theology is not religion any more than psychology is human life, or zoölogy animal life, or botany plant-life. Theology is objective, religion is subjective. Theology is the scientific classification of what is known of God; religion is a loving obedience to God's commandments. Every religious man must have a theology, but it does not follow that every theologian must have a religion. There may be a conflict between theology and some other sciences, and religious men may deplore it," etc. Now, in our opinion, if every religious man must have a theology, and if his theology be in conflict with science, he must either be in conflict in opinion with that science or abandon his theology. But the truth is, that the real, *actual* conflict arises from the religious element. The conflict of opinion is in the theology of a man; the conflict, as it appears upon the stage of the world's history in acts and deeds, has sprung from the religious nature, even as defined by Dr. Deems. A man may hold what theological views you please and make no disturbance in the world, provided he does not think much about his duty in obeying the commands, word, or will of God, all of which are a part of his theology. For instance, one of the commands of God, as contained in his word, and to which he should render a "loving obedience," is "Suffer not a witch to live." Now, a man may believe in that command simply as a dogma, but, being indifferent in the matter of rendering a loving obedience, he will not let it influence his conduct, and so will make no effort to hunt up and have witches burnt. If, on the contrary, he has a loving obedience to God's word, he will trample upon every kindly feeling and instinct of his nature rather than not have the command carried out.

Accordingly, we find that it has been the pious, the sincere, the believers in duty, those wishing to render a loving obedience to God's word, or what they thought was his word, who have in every age been the persecutors. But you say that they were acting under a delusion. They mistook what was the word of God. But how are they to know what is his word, if direct commands like the foregoing are not his? Besides, if there was a mistake, it was in their theology, and not in their religion; that only impelling them to lovingly obey God's commands as they knew them. Religion is but an impulse, a blind instinct. It knows nothing about weighing and comparing opinions. Theology furnishes it with these. If these are bad, its conduct will be bad; if good, the conduct will be good. All it knows is blind obedience—zeal to do the will of God as it knows it; and the pretended science, which alone can give it guidance, is a science of the Unknowable, the Infinite, the Absolute.

We will close with a quotation from Lecky's "History of Rationalism," in reference to Luther: "He was subject to many strange hallucinations and vibrations of judgment, which he invariably attributed to the direct agency of Satan. Satan became, in consequence, the dominating conception of his life. In every critical event, in every mental perturbation, he recognized satanic power. Fools, deformed persons, the blind and the dumb, were possessed by devils. Physicians, indeed, attempted to explain these infirmities by natural causes; but those physicians were ignorant men—they did not know all the power of Satan. Every form of disease might be produced by Satan or his agents, the witches; and none of the infirmities to which Luther was liable were natural; but his earache was peculiarly diabolical. Hail, thunder, and plagues, are all the direct consequence of the intervention of spirits. Many of those persons who were supposed to have committed suicide had in reality been seized by the devil and strangled by him, as the traveler is strangled by the robber. The devil could transport men through the air. He could beget children; and Luther himself had come in contact with one of them. An intense love of children was one of the most amiable characteristics of the great Reformer; but on this occasion he most earnestly recommended the reputed relatives to throw the child into the river, in order to free their house from the presence of the devil. As a natural consequence of these modes of thought, witchcraft did not present the slightest improbability to his mind. In strict accordance with the spirit of his age, he continually asserted the existence and frequency of the crime, and emphatically proclaimed the duty of burning witches."

We see what a loving obedience to the word of God led Luther to recommend. That this spirit has died out, is wholly due to the advancement of science and rationalism, and not to any change in the religious spirit *per se*, or to any different interpretation of the Bible. The witchcraft is there, as it was in the days of Luther, and the injunction not to suffer witches to live is there, and neither has been explained any better than it was in the middle ages. But the researches of the investigators of Nature have gradually driven these notions out of the minds of men, and stamped them with the opprobrium of absurdities.

GREELEY, COLORADO, *February* 14, 1876.

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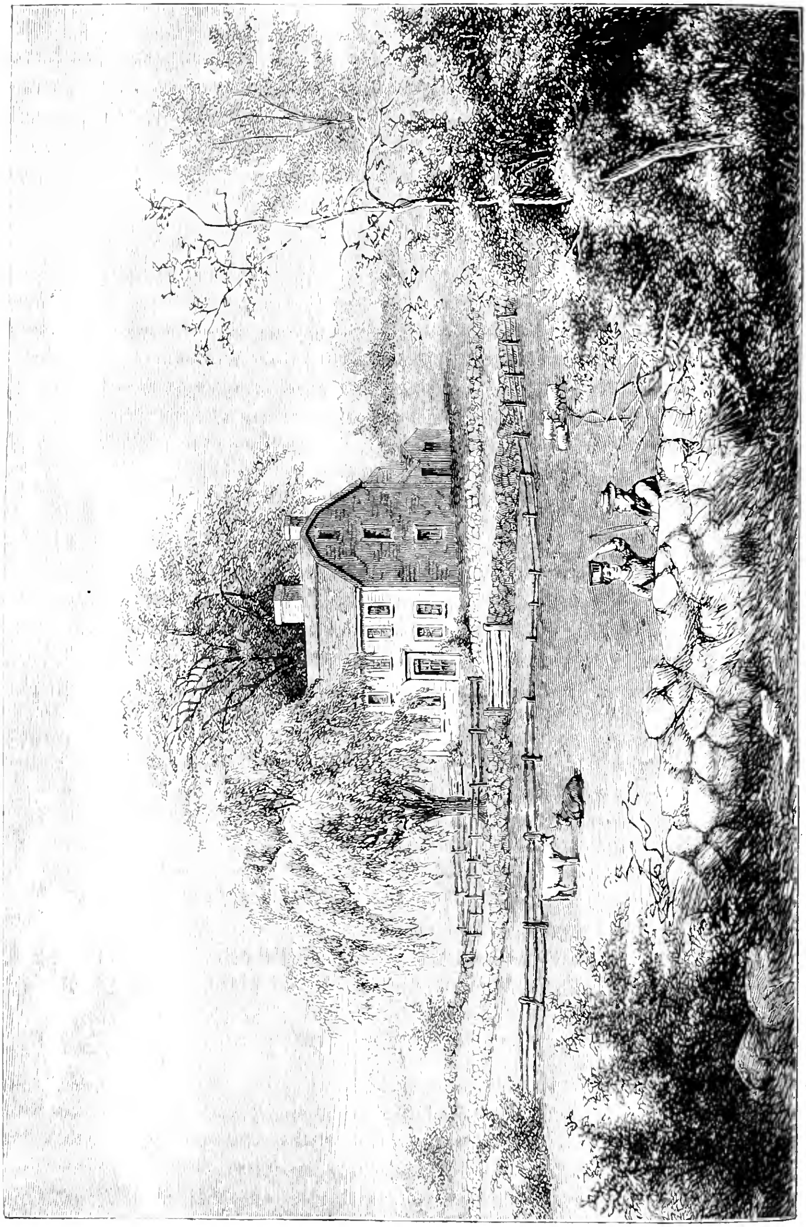
## SKETCH OF BENJAMIN THOMPSON (COUNT RUMFORD).

IN his late work, "Recent Advances in Physical Science," Prof. Tait, of the University of Edinburgh, has attempted a history of dynamical science, or rather of the doctrine of the conservation of energy. Though this great doctrine is recent in its completer development, Prof. Tait holds that it is implied in Newton's laws of motion, and that Newton only failed to grasp it in its modern form for lack of certain experiments. Where Newton broke down, there the subject remained for more than a hundred years, no physicist appearing who could take up the research at that point and carry it on. Prof. Tait says that "what Newton really wanted was to know what becomes of work when it is spent in friction." The experiments thus needed to open the way to a new era in the doctrine of forces were supplied



Birthplace of Benjamin Thompson, in North Woburn, Massachusetts.

by a self-educated American, the subject of this sketch. The newspapers say that he is dropping out of memory in this age, and was in his day a distinguished smoke-doctor and improver of fireplaces; but in the scientific world his fame has been increasing in recent years, and is destined to grow brighter with the further progress of physical knowledge. As attention has latterly been drawn to what America has done for science, it is desirable to give an account of the career and labors of this eminent American investigator.

Benjamin Thompson was born March 26, 1753, in Woburn, Massachusetts. He first saw the light in the west end of a substantial farmhouse, which is still standing a few rods south of the meeting-house in North Woburn. The dwelling is said to be well preserved, retaining its external and internal appearance unchanged, notwithstanding its great age, and it has been recently purchased by the citizens of Woburn, to be preserved as an object of public and historical interest. His father died in his infancy, and when the child was three years old his widowed mother was married to Josiah Pierce, Jr., of Woburn. His latest biographer, Mr. George E. Ellis, says that the lad "indicated from his early years an inconstancy and indifference to the homely routine tasks and the rural employments which were required of him, while at the same time he exhibited an intense mental activity, a spirit of ingenuity and inventiveness, and was found seeking for amusement in things which afterward proved to lead him to the profitable and beneficent occupations of his mature life. He showed a particular ardor for arithmetic and mathematics, and it was remembered of him afterward that his play-time and some of his proper work-time had been given to ingenious mechanical contrivances, soon leading to a curious interest in the principles of mechanics and natural philosophy."

He received the rudiments of a common-school education, and his guardians, finding that he was unfit for a farm-drudge, apprenticed him at thirteen to a merchant in Salem. While thus engaged, with such spare time and private assistance as he could get, he studied algebra, trigonometry, astronomy, and even the higher mathematics, so that before the age of fifteen he was able to calculate an eclipse. At sixteen he was sent to Boston to continue the dry-goods business, and there attended an evening French school. In 1771 he began the study of medicine with Dr. John Hay, of Woburn, and at the same time attended a few lectures at Cambridge. He taught school for a short time at Bradford on the Merrimack, and afterward taught in an academy in Concord, New Hampshire, higher up the same river, a town which had been formerly known as Rumford.

"When Benjamin Thompson went to Concord as a teacher he was in the glory of his youth, not having yet reached manhood. His friend Baldwin describes him as of a fine manly make and figure, nearly six feet in height, of handsome features, bright blue eyes, and dark au-burn hair. He had the manners and polish of a gentleman, with fascinating ways, and an ability to make himself agreeable. So diligently, too, had he used his opportunities of culture and reading, that he might well have shone even in a circle socially more exacting than that to which he was now introduced. We may anticipate here the conclusion to which the review of his whole career will lead us, that, as boy or man, he was never one to allow an opportunity of advancement to escape him." At Concord, when nineteen years of age, Mr. Thompson married Sarah Walker Rolfe, a wealthy widow, aged thirty-three, and by whom he had a daughter.

The Revolution was now fermenting, and alienations and discords were springing up among the people. Young Thompson had made the acquaintance of Governor Wentworth of New Hampshire, who, discerning his genius and promise, gave him the military commission of major. This aroused a bitter feeling of jealousy not only in the subordinate officers over whom he had been sprung, but also with his superiors, who were all turned into effective enemies. His independent manners, his intimacy with the royal governor, and, perhaps, inconsiderate words in a time of excitement, led to the suspicion and the charge that Thompson was unpatriotic and sided with the royalists. By the potency of gossip and tale-bearing he was brought under suspicion of Toryism, and threatened with that dignified discipline of outraged patriotism, tar and feathers and riding on a rail. Thompson indignantly denied the accusation. He called for proof, and a meeting of his townsmen was called to consider his case. But no evidence of any kind was produced against him. Nevertheless the adverse feeling in Concord was so strong that he found it necessary to leave. There can be little doubt of the brutal injustice with which Thompson was treated. His biographer writes with evident impartiality, and presents the case in all its aspects, and, admitting that nothing bearing the character of evidence was to be found against his patriotism, hes ays that "Major Thompson insisted from the first, and steadfastly to the close of his life affirmed, that he was friendly to the patriot cause, and had never done or said anything which could be truthfully alleged as hostile to it." The simple fact seems to be that while young Thompson entertained, and probably expressed, his doubts about the issue of a conflict with the mother-country, as many other independent-minded men must have done, he was nevertheless in sympathy with the patriot cause, and was not only willing to devote himself to it, but earnestly sought the opportunity by petitioning the Provincial Congress for a position in the army. But he was defeated through the machinations of the officers who resented his appointment by Wentworth. His biographer says: "He lingered about the camp. He devoted himself zealously to the study of military tactics. He continued his experiments on gunpowder. He strolled between Woburn, Medford, Cambridge, and Charlestown, learning whatever his inquisitive mind could appropriate. But there was one set of men whom he never could conciliate, who mistrusted his purposes, and cast upon him lowering looks as they met him about the camp. These were the general and field officers from New Hampshire, who looked upon him as a dandy and an upstart at least, if not also at heart a traitor. They would not associate with him, still less confide in him." It is further stated on authority, that there is no reason for doubting that "after the battle at Charlestown, Thompson was favorably introduced by some officers of Cambridge to General Washington, who had just assumed the command; and that, had it not been for the opposition of some of the New Hampshire officers, he would have had the place in the American artillery corps which was given to Colonel Gridley." The genius of Thompson was thus lost to the American cause through the rivalries and hatreds of army officers, a source of evil which profoundly troubled the life of Washington during the Revolution, as it did also that of Lincoln during the civil war.

Nothing was therefore left to Thompson but to remain in obscurity at home under a cloud of suspicion that would have darkened his life, or to seek a field of action elsewhere. He was a man of high spirit and great force of character, and of course would not submit like a poltroon to the degrading alternative. He accordingly took service under the government of his early allegiance. He went to England, and soon after his arrival, at the age of twenty-three, was given an appointment in the colonial office, under Lord George Germaine. He directed immediate attention to military matters; improved the accoutrements of the Horse-Guards; continued and extended his experiments on gunpowder, and improved the construction of firearms. He experimented with great guns, made a study of the principles of naval artillery, and devised a code of marine signals. He also made investigations into the cohesion of bodies, which he communicated to Sir Joseph Banks, President of the Royal Society, and was elected Fellow of that body in 1779 at the age of twenty-six. He very soon became one of the most active and honored members of the Royal Society, always attending its meetings when he was in London. He afterward received a colonelcy from the British Government, and came back to this country in command of a regiment on Long Island, building a fort at Huntington. He returned to England in 1783, and the same year made a tour on the Continent. At Strasburg he accidentally met with Prince Maximilian of Deux Ponts, then field-marshal in the service of France, who became so interested in Colonel Thompson that he gave him an introduction to his uncle the Elector of Bavaria at Munich. The Elector was a man of liberal views, and discerning in Thompson the talent that he thought might be made available in promoting the interests of his government and people, he made overtures to him to enter his service in a joint military and civil capacity. The proposition was favorably received, but, as Colonel Thompson was a half-pay officer of the English crown, he needed to have the permission of the king before making a Continental engagement. He therefore returned to England in 1784, and received not only the king's permission, but also the honor of knighthood and the continuance of his half-pay, and he returned to Munich the same year as Sir Benjamin Thompson. A splendid field was now before him, and he entered upon a series of the most remarkable labors, to which he devoted himself with great assiduity. "These labors ranged from subjects of the homeliest nature in their bearings upon the thrift, economy, and comfort of life for the poorest classes, through enterprises of wide-extended and radical reform, and comprehensive benevolence, up to the severest tests and experiments in the interests of practical science." . . . . "The elector was from first to last his constant friend, never thwarting him, never holding back his aid; but, on the contrary, ready always to advance every plan of his, and to espouse his views when questioned or opposed by other counselors."

It is impossible, in this brief sketch, even to enumerate the extensive and important measures of public beneficence and social amelioration which Sir Benjamin projected and successfully carried out. He reorganized the entire military establishment of Bavaria, introduced not only a simpler code of tactics and a new system of order, discipline, and economy, among the troops and industrial schools for the soldiers' children, but greatly improved the construction and modes of manufacture of arms and ordnance. He devoted himself to various ameliorations, such as improving the construction and arrangement of the dwellings of the working-classes, providing for them a better education, organizing houses of industry, introducing superior breeds of horses and cattle, and promoting landscape-gardening, which he did by converting an old abandoned hunting-ground, near Munich, into a park, where, after his departure, the inhabitants erected a monument to his honor. He moreover suppressed the system of beggary, which had grown into a recognized profession in Bavaria and become an enormous public evil—one of the most remarkable social reforms on record. Mendicity in Bavaria was at that time "a stupendous and organized system of abuses, which, gradually growing upon the tolerance of the government and people, had reached such proportions and had established itself with such a vigorous power of mischief as to be acquiesced in as irremediable. Beggars and vagabonds, the larger part of whom were also thieves, swarmed all over the country, especially in the cities. These were not only natives, but foreigners. They were of both sexes and all ages; they strolled in all directions, lining the highways, levying contributions with clamorous demands, entering houses, stores, and workshops, to rob, interrupting the devotions of the churches with their exactions, and extorting everywhere, through fear, what they failed to get by importunity. These swarms of mendicants and freebooters were in the main composed of strong, healthy, and able-bodied persons, who preferred an easy life of indolence to any kind of industry. They had become the terror and scourge of the country. They would steal, maim, and expose little children, and compel them to extort, by their piteous appeals, a fixed sum for a day's gatherings, with the threat of an inhuman punishment if they failed. Every attempt to suppress this system of outrages having been thwarted, the community had learned to submit and conform to it as admitting of no relief; and this wretched tolerance seemed to double the number of these vagabonds, while it raised beggary into a profession." So systematic and rooted had this state of things become that "the beggars formed a caste in the cities, with professional rules, assigning to them beats and districts, which were disposed of by regulations, in case of the death, promotion, or removal, of the proprietors.

Sir Benjamin resolved upon the extirpation of this system, and the conversion of this lazy and dissolute class into thrifty, self-sustaining laborers. His policy was cautious, deliberate, and wise. He knew exactly what he wished to do, made ample provision for it, and secured the coöperation of the influential classes in the execution of his plan. We cannot describe it here, but its success was complete. The beggars were swept from the streets, cared for, soon set to work, and raised to a condition of self-respecting industry. So effectual was the work that Sir Benjamin won the heart-felt gratitude of the very class upon which he had operated. This is beautifully illustrated by the fact that, "on one occasion, when he was dangerously ill, the poor of Munich went publicly in a body to the cathedral and put up public prayers for his recovery. And again, when, four years afterward, they learned that he was in a similar condition at Naples, they of their own accord set apart an hour each evening, after they had finished their work in the military workhouse, to pray for him."

For the valuable services rendered in Bavaria Sir Benjamin received many distinctions, and, among others, was made Count of the Holy Roman Empire. On receiving this dignity he chose a title in remembrance of the country of his nativity, and was henceforth known as Count of Rumford. His health failing from excessive labor, and what he considered the unfavorable climate, he came back to England in 1798, and had serious thoughts of returning to the United States, having received from the American Government the compliment of a formal invitation to revisit his native land. While in England, Count Rumford organized the Royal Institution of Great Britain in 1800, which was designed for the promotion of original discovery and the diffusion of a taste for science among the educated classes. Its success has more than vindicated the sagacity of its founder. He afterward returned to the Continent, and, while frequently visiting Munich, took up his residence in Paris. In 1805 he married the widow of the celebrated French chemist Lavoisier, who was beheaded in the French Revolution. The union, however, not proving a happy one, they soon separated, and Rumford died in his residence at Auteuil the 21st of August, 1814. His first wife had died in 1792, and his daughter, who inherited his title, had come to him at Munich, and returned to America after her father's decease.

The philanthropic interest of Count Rumford in the poor and defective domestic life of the lower classes of society had a great influence in determining the course of his scientific inquiries. It was this feeling that led him to investigate the properties and domestic management of heat. He determined the amount of it arising from the combustion of different kinds of fuel, by means of a calorimeter of his own invention. He reconstructed the fireplace, and so improved the methods of warming apartments and cooking food as to produce a saving of from one-half to seven-eighths of the fuel previously consumed. He improved the construction of stoves, cooking-ranges, coal-grates, and chimneys, and showed that the non-conducting power of cloth is due to the air inclosed among its fibres; and he first pointed out that mode of action of heat called convection; indeed, he was the first clearly to discriminate between the three modes of propagation of heat—radiation, conduction, and convection. He determined the almost non-conducting properties of liquids, investigated the sources of the production of light, and invented a mode of measuring it. He was the first to apply steam generally to the warming of fluids and to culinary operations. He also, as has been stated, experimented extensively upon the use of gunpowder, the strength of materials, and the maximum density of water, and made many valuable and original observations upon an extensive range of subjects, which are described in the essays recently for the first time published in a complete form. As Prof. J. D. Forbes remarks, "all Rumford's experiments were made with admirable precision, and recorded with elaborate fidelity and in the plainest language. Everything with him was reduced to weight and measure, and no pains were spared to obtain the best results."

But it was his investigations concerning the nature of heat that will make him immortal. By experiments in boring cannon he proved its immateriality, and that it does not consist of an imponderable substance or fluid, as implied by the old theory of caloric. In these experiments he demonstrated that the heat generated by friction does not come from any latent source in the materials used, but is derived from the power spent in producing the friction; that its amount is in the ratio of the power expended; that it is a case of the transformation of energy, and a mode of molecular motion. He was half a century in advance of his age, and his researches were long unappreciated; but they are now recognized as forming an epoch in the progress of physical science.

# CORRESPONDENCE.

### "WHAT CONSTITUTES RELIGION?"

*To the Editor of the Popular Science Monthly.*

DEAR SIR: The use of my name twice in your notice of Mr. Fiske's new work on "The Unseen World," in your May number, perhaps justifies me in soliciting a small space for comment on some expressions in that notice.

You are defending Dr. Draper from Mr. Fiske's trenchant attacks. To that there can be no objection. Confederates are justified in standing by one another; but I do not think that you are justified in saying that "the point of contention is as to what constitutes religion." So far from there being contention on that point, there is really no important difference. All "sects," no matter how much they "eat each other up in their denial of dogmas," as you affirm, agree as to what religion is. It does not seem edifying to behold in you the temper which dictates the first of the following sentences, although the exceeding generosity of the careful proposal in the second has a redeeming flavor. "We hope that the agreement of Messrs. Brownson, Hill, Washburn, Deems, Fiske & Co., in denouncing the groundlessness of the 'conflict,' will not be construed as implying any agreement among the parties as to what religion is. If these gentlemen will get together and settle the point, an important step will be gained, and THE POPULAR SCIENCE MONTHLY will gladly pay the expenses of a convention of reasonable length for such a purpose; but we stipulate not to foot the bills until they reach an agreement."

For the other gentlemen I cannot answer, but I simply say that I never did "*denounce* the groundlessness of the conflict," but have announced it and endeavored to demonstrate it, and you are witness that I am "vehement in *asserting* the groundlessness and absurdity of Dr. Draper's assumption" of the conflict (page 113).

Why are you so anxious to keep your readers from believing that the gentlemen whose names you have recited in fact do not and really cannot agree as to what is "religion?" Have you ever seen anything in our writings or heard anything in our oral teachings to justify the supposition that we do not agree? As you challenge us, I accept the challenge for my part. I will not expose you to the cost of a convention, but here, in my study, without consultation with any of the other gentlemen you name, I venture to give two definitions of religion, in both of which I venture to predict that all those gentlemen, if they see this letter, will heartily agree, and that these definitions will win the assent also of Archbishop McCloskey, Bishop Potter, Bishop Foster, Bishop Wightman, Chancellor Crosby, Rev. Dr. Armitage, and Rev. Dr. Storrs, representatives of the leading "sects."

To give the least first, here is my own definition: Religion is *loving obedience to God's will.* No matter how or where that will is discovered, nor what it is, he is a religious man who does what he believes will please God, because he loves God.

The second is authoritative. It is that of St. James (i. 27): "True religion and undefiled before God and the Father is this: To visit the fatherless and widows in their affliction, and to keep himself unspotted from the world." A life of inward purity and outward beneficence is a religious life.

I venture to think you may pass these around the whole circle of religionists and find unanimity. But do not we religionists disagree? Certainly. The five gentlemen you have mentioned, and the seven whom I have named, differ more or less, oftener more than less, and on some points apparently irreconcilably. But mark: we never differ in our religion; it is in our science. The moment two men become scientific, whether they are religious or not, they begin to "eat each other up in their denial of dogmas." So long as we keep to religion, we are one. Our *hearts* are together. It is only with our *heads* that we butt one another. I have worshiped God in company with each of the seven distinguished clergymen whom I have ventured to name, and yet there is not one of them who does not hold some dogma of doctrine or ecclesiasticism to which I cannot subscribe. As religionists, we agree. As scientists, we differ. It is on the ground of our theology that we differ, and that is purely a scientific ground. Be pleased always to remember that theology is only a science like geology or biology.

But, my dear sir, we theologians would be out of fashion if we did not "eat each other up in our denial of dogmas." All *other* scientists do. The dogma of heterogenesis tries to "eat up" the dogma of homogenesis, while the dogma of pangenesis is fairly bursting itself to swallow both the others bodily; and there is no small conflict between spontaneity and heredity, and meanwhile biosis is striving vigorously to hold its ground against archebiosis.

Behold! are not Religion and Life the two greatest subjects? You are quite anxious that your readers shall fancy that religionists cannot agree in their definitions of religion. But you do not show them that even on the subject of Life the scientists are greatly at difference. Prof. Owen says that "Life is a sound;" Schelling says it is a "tendency." Herbert Spencer calls it "a continuous adjustment." Dr. Meissner says it is "but motion." Dr. Bastian holds that he has produced plants and animals from inorganic matter. Schultz positively believes it never was done and cannot be done: and Prof. Huxley holds that "constructive chemistry could do nothing without the influence of preëxisting living protoplasm."

I do not wish to crowd your pages, and so content myself with these few instances out of the multitudes of conflicting and perplexing differences among "advanced thinkers."

Even you, my dear sir, have not utterly escaped. You once wrote, "If the forces are correlated in organic growth and nutrition, *they must be* in organic action." Manifestly, after that sentence was written, you meditated, and, meditating, you discovered that the *sequitur* was not quite as apparent as it ought to be. You did not strike out the sentence, but you apologized for it handsomely by saying, "From the great complexity of the conditions, the same exactness will not be expected here as in the inorganic field." But you see, my dear sir, that theology is a science which has for its field those subjects in which there is the greatest complexity of conditions, and you must not demand of your brother scientists as much exactness in the statements of a metaphysical proposition as you may in the statement of the length of a fish's tooth.

But as to your statement that *the forces must be correlated in organic action*, are you not in danger of being "eaten up" by the statements of your friends, Bastian, Barker, and, what is still harder on you, Herbert Spencer? Prof. Barker teaches that the correlation of the natural forces with thought "has never yet been measured." Then, it is a mere "guess." Dr. Bastian says that it "cannot be proved" that sensation and thought are truly the direct results of molecular activity. Then it is a mere "guess." Mr. Herbert Spencer, whose name is conclusive authority with you, and who, I am most frank to admit, knows as much about the "unknowable" as any writer whose works I have read, says that the outer force and the inward feeling it excites "do not even maintain an unvarying proportion." Then it is a mere "guess." And, my dear sir, I do most heartily agree with your statement, "not he who *guesses* is to be esteemed the true discoverer, but he who *demonstrates* a new truth."

Now, if Messrs. Spencer, Barker, Tyndall, Huxley, Büchner, Draper, Youmans, "& Co.," will "get together and settle" what Life is, or Thought, "an important step will be gained;" and, not to be outdone by your generosity, I will engage to "pay the expenses of a convention of reasonable length for such a purpose," but I "stipulate not to foot the bills until you reach an agreement."

Trusting that both you and I, as we grow older, may have more science and more religion, and room enough in our heads and hearts for both without "conflict,"

I am, very faithfully, your co-laborer,
CHARLES F. DEEMS.

Of course Dr. Deems meant to announce, assert, and declare, the groundlessness of the conflict between Religion and Science; and we think the readers of our article which he criticises were not in the slightest danger of misapprehending his position, notwithstanding the slip of writing in which he is said to have *denounced* it.

Dr. Deems asks: "Why are you so anxious to keep your readers from believing that the gentlemen whose names you have recited in fact do not, and really cannot, agree as to what is religion?" Has not the doctor here slipped also, in inadvertent haste, and does he not really mean, Why are you so anxious *to make your readers believe*, etc.? and to this we reply, that the anxiety in regard to a definition of religion has not originated with us. It is the reviewers of Dr. Draper who have called for a definition of religion from him, and condemn his book as dealing with a "conflict" existing only in his own imagination, because he has not defined what religion is. Had he undertaken this, they tell us, it would have at once appeared that there is and can be really no such conflict. We said that "the point of contention is as to what constitutes religion," because the theological reviewers of Draper charge that what he treats as religion, and as conflicting with science, is not religion. We have not denied that religion can be so defined as to avoid all antagonism with science; and there is hope that the time may come when such a definition will be accepted and the antagonism will disappear. We only maintain that in the historic past, with which Dr. Draper deals, such an interpretation of religion had not been reached, and that it is very far from being arrived at at the present time. Dr. Draper has been reproached for not defining religion; had he done so, and had his definition described that which has passed under the name of religion, and been held as religion, generation after generation, his definition would have been at once repudiated by the theological party. We said that those who agree in demanding a definition of religion from Dr. Draper, and condemn his book as treating of an illusive conflict because he does not furnish it, cannot themselves agree upon the definition they profess to so much desire. Does Dr. Deems accept Mr. Fiske's definition? And if there is one definition, clear and complete, which all men can adopt, why does he bring us two, and which are we to accept? They are certainly not identical, for one makes it consist in a special relation of man to God, and the other in charity and moral purity. Dr. Deems defines religion as "loving obedience to God's will;" but if the obedience is inspired by Calvinistic fear, is it religion or not? Loving obedience to God's will—but how ascertained? Dr. Deems may say, with broad liberality, either by the study of God's printed word, or by the study of his living works; but can he insure us an agreement among all parties upon this basis? From the doctor's position, that religious people disagree among each other on account of their science, we respectfully dissent. Science is not an agency of discord, but of concord. There are undoubtedly disagreements in science, for its nature is progressive, and diversities of view are inevitably incident to its imperfect stages. Yet the great law of scientific thought is that, with the progress of investigation, there is ever a tendency to wider agreement, until its truths at length become established and universally accepted. Throughout civilization it is in science, and, we might almost say, in science alone, that men are brought into essential agreement. Through the power it has conferred over the elements of Nature have come the marvels of modern international communication and intercourse; and through the truths it has established in the domain of experience has come a body of common belief, which men of all languages, religions, and nationalities, can accept, so that we must regard science as in fact the predominant unifying agency of the world. The reason is, that it deals with the order of Nature, which is constant and ever open to observation and research. New questions are, of course, constantly arising in science, upon which there are at first wide contrasts of opinion, but the history of science abundantly shows, either that such questions are gradually cleared up, or, if this is found to be impossible—if the truth cannot be determined about them—then there comes agreement in this, and they are finally put aside as insoluble, and therefore questions with which science has no legitimate concern. Conflicting views now prevail on the problems of the origin of life and the nature of life, and time alone can determine what will be the issue of these inquiries; but we submit that these diversities of opinion are of a quite different kind from those between the Unitarian and the Trinitarian—the Universalist and the Perditionist.

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# EDITOR'S TABLE.

### *WHO SHALL STUDY THE BABIES?*

THE reader's attention will be arrested by the novelty of our first article, by a distinguished literary Frenchman, giving the result of his observations on the progress of an infant in learning to talk. We confess to some mortification at seeing the name of a man at the head of such a discussion. Not that the dignity of M. Taine is at all compromised, for he never undertook a more important or a more distinguished task than critically noting the steps of mental evolution in a baby. Nevertheless, this would seem to be preëminently the proper work of woman—a work to which we might infer she would be drawn by her feelings, in which she would be interested by her curiosity, and would take up from the temptation of her special opportunities. Yet M. Taine found that it had not been done. He wished to test Max Müller's views in regard to the genesis of language, and wanted a series of observations of infantine mental growth for the purpose. But they had not been made, the facts were wanting, and nothing remained but to make the study himself. We say this kind of work belongs to woman, and she is perfectly competent to peform it. Why, then, has it not been undertaken, and why has there not grown up a body of carefully-observed and widely-verified facts regarding psychological development in infancy such as would be valuable for arriving at inductive truths for guidance in the rational education of childhood? Undoubtedly, psychology is a backward science, imperfect from the obscurity and complexity of its questions, and its long cultivation by unscientific methods. But the value of observations upon the mental unfolding of infancy is not, by any means, dependent upon the possibility of immediately explaining them. Such observations, if accurately made and intelligently recorded, will have a value of their own independent of the state of psychological science, while they would become a permanent and potent means of its advancement. In most other fields of natural phenomena the facts are far in advance of the theories by which they are organized into science; in the field of mental growth, however, observations are scanty and speculation superabundant.

We are, of course, not to expect that things will come before they are wanted, and, if such observations are not called for, why should they be supplied? But the facts have been long and loudly called for, if not by psychologists, then by practical educators, while woman has had exclusive charge of the education that begins in infancy. She is an educator as a mother, and the culture of childhood has almost universally fallen into her hands as a teacher. We might surely have expected that, with their great excess of opportunity, some few women of ability would have gone carefully and critically and often over the ground which M. Taine has passed over once with such interesting results. But the work that might have been expected, so far as we are aware, has not been done, nor is there any promise of it. The difficulty is, that there has been nothing in woman's education either to interest her in the subject or to qualify her for dealing with it. Observations, to be valuable for scientific purposes, involve an accuracy of perception and an intellectual discrimination which are not to be had except by patient and methodical training of the observing powers. This is the one thing that has not been included in female education. Neither languages, nor mathematics, nor history, nor mental philosophy, nor music, nor general literature, affords any exercise whatever of the observing faculties. A student may become proficient in all these branches, while the intellectual interest in the phenomena of daily experience, and the objects of common life, remains as dormant as it is in the savages. Nay, more, absorption in these modes of mental activity, which involve chiefly the memory and reflective powers, is fatally unfavorable to observation, as it brings the mind under the control of mental habits that exclude it. No woman can make valuable observations on mental progress in infancy that has not had a culture fitted for it, first, by a long practice, such as she gives to music, in independent observation in some branch of objective science, as botany, for example; and, secondly, by a thorough knowledge of the constitution of the child, especially the functions of its nervous mechanism. With their heads filled with history, æsthetics, algebra, French, and German, they will never attain to these qualifications for studying the character of children. The seminaries do not prepare them for it; the high-schools and the normal schools do not confer it. Nor is this all, nor the worst. There is no appreciation of it or aspiration for it. The so-called woman's movement, which professes to aim at her higher improvement and the enlargement of her activities, is not in this direction. It looks to public, professional, and political life, as woman's future and better sphere of action. In the new colleges for women that are springing up in all directions with munificent endowments, the supreme consideration seems to be to ignore sex, and frame the feminine curriculum of study on the old masculine models, and keep it up to the masculine standards. The spirit of these schools is that of a slavish imitation. They are organized with no reference to the urgent and living needs of society, but they go in for the traditional trumperies of the old colleges; and, instead of studying science in its personal, domestic, and social bearings, the women demand Latin and Greek, and as much of it as the masculine intellect has proved capable of surviving. Children are imitators. Savages are imitators. What else are the women in their demands for new and ampler opportunities of culture? They will study classics, and let the men study the babies; but, if they are incompetent, of course the men *must* do it. For this business of studying the science of infancy must be pursued by somebody, thoroughly and exhaustively. It is nothing less than a transcendent problem of human character lying at the foundation of the social state; for only as the human being is understood in its deeper organic laws, prenatal and infantine, as well as in its subsequent unfolding, can we arrive at settled and scientific views regarding the rights, claims, duties, and true interests of the individual in society. If not a new research, it is at least a new impulse and stage of research, and we say again that we should think intelligent and ambitious women would be glad to have a share in it, and would have wisdom enough to include it in their extended schemes of female education.

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### *ENGLISH PHILOSOPHY IN GERMANY.*

We not long ago called attention to a newspaper article under the title of "German Darwinism," which made a point against Herbert Spencer as not being recognized in Germany. We pointed out various reasons in the national habits of thought, why Spencer's doctrines, which are put forth under the form of a philosophical system, would be likely not to attract the attention of German thinkers so early as those of other Continental countries. Our view has since been strikingly confirmed by an eminent German authority, Prof. Wundt, of the University of Leipsic, a physiologist and psychologist of world-wide reputation. In a review of the German translation of "First Principles," published in the Jena *Literary Gazette*, Prof. Wundt gives an excellent account of the book, from which the following statements are condensed:

"Of living English philosophers Herbert Spencer undoubtedly stands in the foremost rank, yet his works have hitherto been little known in Germany. It would, however, appear that this neglect is soon to be retrieved, for, simultaneously with the appearance of the work under review, two other volumes by the same author are issued. By giving an excellent translation of 'First Principles' (under the title of 'The Bases of Philosophy'), Dr. Vetter has rendered good service to his countrymen, and it is to be hoped that he will further aid in making this distinguished author known in Germany by translating the subsequent volumes of his system."

"In the whole tenor of his views Mr. Spencer differs widely from the speculative philosophers of Germany. The indomitable persistency with which for twenty-five years he has worked on the various branches of science, bringing them into one system, has no parallel in Germany, save, perhaps, in Hegel's 'Encyclopædia.'"

"Among the dominant ideas in this system the doctrine of evolution is preëminent. In Spencer's mind evolution is not merely a principle in biology, but extends on the one hand to inorganic Nature, and on the other hand to the domain of psychology and sociology. And here we take occasion to remind the reader that, independently of the stimulus given to scientific thought by Darwin, Mr. Spencer early recognized the importance of the law of evolution, to which from the first he gave very wide scope, and which he has illustrated with a multitude of original ideas."

"A detailed criticism of the 'First Principles' would necessarily require a book for itself, more especially because the German reader, from the very nature of his philosophical training, will enter on the study of the most general laws of being, the demonstration of which is the aim of the present work, with prepossessions different from those of the English author. Perhaps in the philosophical literature of recent times there is no English work which bears the national stamp so visibly as does Spencer's. From this point of view alone, to say nothing of the many pregnant thoughts it contains, it well deserves the attention of German readers. John Stuart Mill, in the philosophical direction of his mind, came too much under the influence of the French, particularly of Comte. Spencer's mind is, no doubt, more original than Mill's, and more free from foreign influences, though inferior in the splendor of external form. In all the philosophical speculations of Spencer we plainly see that practical sense which makes its way through the most difficult problems by the shortest route."

"Finally, though the German reader will find in these 'Bases of Philosophy' much that he will object to, and though on the capital points of the system he will dissent from the author oftener than he agrees with him, nevertheless he will not lay the book aside without having received many a valuable suggestion. Indeed, it may be truly said of works on philosophy, that we learn more from those which arouse our opposition than from those which merely echo our own opinions."

## *THE RUMFORD MEDALS.*

The Rumford gold medal of the American Academy of Arts and Sciences, founded to commemorate important contributions toward our knowledge of heat and light, has just been granted to Dr. John William Draper, of New York. This is a distinguished tribute to the scientific labors of our eminent physicist and chemist, and the Academy has honored itself in the award. Yet, those who know how early and eminent were Dr. Draper's original contributions to the chemistry of light, will be tempted to ask why this distinction was not accorded by the Academy to Dr. Draper a generation ago. As reminiscences of Count Rumford are being revived just now, it will be interesting to glance at the history of his medals, which have attained such celebrity in the scientific world.

Deeply impressed with the importance of extending the knowledge of heat and light, to which he had devoted himself with great assiduity and success, Count Rumford, in 1796, presented to the Royal Society £1,000, the interest of which was to be spent in striking two medals both in the same die, one of gold and one of silver, worth the interest of the donation for two years, and to be given biennially for the most important discovery or improvement relating to heat and light that should have been made during the preceding two years in any part of Europe. The trust was accepted and the medals designed. The first award was to Rumford himself in 1802. In 1804 John Leslie received the Rumford medals. The honor then passed, in 1806, to Murdock; in 1810 to Malus; in 1814 to Dr. Wells; in 1816 to Humphry Davy; in 1818 to David Brewster; in 1824 to Fresnel; in 1834 to Melloni; in 1838 to J. D. Forbes; in 1840 to Biot; in 1842 to Fox-Talbot; in 1846 to Faraday; in 1848 to Regnault; in 1850 to Arago; in 1852 to Stokes; in 1854 to Arnott; in 1856 to Pasteur; in 1858 to Jamin; in 1860 to Clerk-Maxwell; in 1862 to Kirchhoff; in 1864 to Tyndall; in 1866 to Fizeau; in 1868 to Balfour Stewart.

At the same time Count Rumford made a corresponding donation to the

American Academy of Arts and Sciences, instituted in 1780. Five thousand dollars were presented, the accruing interest of which was to be invested in medals, and granted biennially by the academy for the most important discoveries in relation to heat or light made within the preceding two years. It was also provided that, if this term passed without any discovery or improvement being made that should be deemed worthy of the award, the accruing interest was to be added to the principal, and the augmented income thus arising was to be added to the medals when the next award was made. But the arrangement seemed to be a futile one, as there were none in America who troubled themselves to extend the knowledge of heat and light; or, at all events, there were no such extensions as in the opinion of the Academy were entitled to win the prizes. Years passed, and the money accumulated until the Academy became embarrassed by the question what to do with it. And so they got a law passed by the Legislature empowering them to depart from the strict letter of the endowment, and use the funds with more freedom in the interest of advancing knowledge. In 1839 the Academy gave from the interest of the Rumford fund the sum of $600 to Dr. Hare, of Philadelphia, in consideration of his invention of the compound blowpipe, and his improvement in galvanic apparatus. The Rumford medal was granted by the Academy, in 1862, to John B. Ericssen for his caloric-engine; in 1865 to Daniel Treadwell, for improvements in the management of heat; in 1867 to Alvan Clark, for improvement in the lens of the refracting telescope; and in 1870 to George H. Corliss, for improvements in the steam-engine. When the gift was made to Dr. Hare, the fund amounted to $27,000; and it has now grown to $42,000.

The biographer of Rumford makes the following significant observation: "It is remarkable that the count, after having liberally provided funds for medals in the award of two learned bodies, should a few years afterward, when drawing his plan and publishing his proposals for his own Royal Institution, have introduced into them an express prohibition of all premiums and rewards."

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# LITERARY NOTICES.

On Fermentation. By P. Schützenberger. With Twenty-eight Illustrations. Pp. 306. Price, $1.50. D. Appleton & Co. No. XX. International Scientific Series.

In the logic of science, the misleading influence of words is a matter of ever-increasing importance. Words remain, but the ideas they represent are altered, expanded, revolutionized. The old and narrow meanings live on in common speech, and the changed and enlarged significations are current among men of science, so that when the terms are employed between these classes they have so totally different a signification that intelligent and critical interchange of ideas between them is hardly possible. The term applied to the present work is a case in point. The word "fermentation" is derived from *fervere*, to boil, and applies to the agitation or effervescence of saccharine liquids when placed in contact with ferments—a phenomenon that was probably familiarly known long before the earliest traces of history. To the mass of people, the word "fermentation" suggests bread-making and brewing, with the production of spirituous and souring products. To the man of science and as treated in the present volume, fermentation has become one of the great gateways to biology. The subject has ever been, and must continue to be, of great practical moment in its domestic and manufacturing relations; and every step in its scientific elucidation is therefore a contribution to the theory and progress of the arts. The knowledge of it has now become so clear and extended, that it was necessary it should be brought together in a special treatise for reference for all who are interested in practical problems of organic chemistry. But while the present book fulfills this condition, it also aims at the higher object of bringing the principles of the subject into relation with philosophical biology. The scientific significance of fermentation lies in the fact that it brings before us the action and effects of the lowest and most elemental forms of living organisms; it deals with the behavior and influence in numerous relations of elementary organisms reduced to a single cell; but these cells are the units of all organic life, a plant or an animal of a higher order being only the union under special laws of different kinds of cells, each of which acts in a certain determinable manner. While the higher organisms baffle analysis from the infinite complexity and diversity of their minute or histological elements, the key to their study is offered in these lower structures, for "the more simple an organism is, the fewer special kinds of cells it contains, the simpler are the chemical reactions which take place in it, and the more easily are they separated from each other and isolated by experiment;" and from this point of view the history of fermentation becomes nothing less than that of the chemical phenomena of life. The thorough study of ferments, therefore, becomes an indispensable scientific prerequisite to the knowledge of the higher organisms.

The investigation of the influence of different ferment-cells in initiating different lines of chemical change brings us into closer quarters with the relations of chemical and so-called vital forces. As the different radiant forces, thermal, luminous, and chemical, produce their profoundly diverse effects simply by variations of wave-length, so the different kind of cells are supposed to initiate different chemical changes by differences in the vibratory rhythm which starts them. In relation to this point our author remarks:

> "The transformation of sugar into alcohol and carbon dioxide and the conversion of the same body into lactic acid are chemical phenomena which we cannot yet reproduce by the intervention of heat alone, nor by the additional agency of light or of electricity. The force capable of attacking, in a certain determinate direction, the complex edifice which we call sugar, an edifice composed of atoms of carbon, hydrogen, and oxygen, grouped according to a determinate law—this force, which is manifested only in the living cell of the ferment, is a force as material as all those which we are accustomed to utilize. Its principal peculiarity is, that it is only found in the living organisms, to which it gives their peculiar character. We ought not to allow ourselves to be stopped by this rampart, over which no one has hitherto been able to pass; we ought not to say to the chemist, 'You shall go no farther, for beyond this is the domain of life, where you have no control.' The history of science shows us the weakness of these so-called impassable barriers. No one can any longer admit that vital force has power over matter, to change, counterbalance, or annul, the natural play of chemical affinities. That which we have agreed to call chemical affinity is not an absolute force; this affinity is modified in numberless ways, according as the circumstances vary by which bodies are surrounded. Thus, the apparent differences between the reactions of the laboratory and those of the organism ought to be sought for, more particularly among the *special conditions*, which the latter alone has been able hitherto to bring together. In other words, there is really no chemical vital force. If living cells produce reactions which seem peculiar to themselves, it is because they realize conditions of molecular mechanism which we have not hitherto succeeded in tracing, but which we shall, *without doubt*, be able to discover at some future time. Science can gain nothing by being limited in the possibility of the aims which she proposes to herself, or the end which she seeks."

MEMOIR OF SIR BENJAMIN THOMPSON (Count Rumford), with Notices of his Daughter. By GEORGE E. ELLIS. Published, in connection with an edition of Rumford's Complete Works, by the American Academy of Arts and Sciences. Boston. Pp. 680.

Rumford's Complete Works, vol. I., pp. 493. Vol. II., pp. 570. Vol. III., pp. 504. Vol. IV., pp. 842. Price of the set, including the "Life," $25.00. Boston: Estes & Lauriat.

WE elsewhere publish a brief notice of the life of Count Rumford—so brief as hardly to give a just idea of the interest that attaches to the romantic and remarkable story of his career. But few biographies are richer in varied incident, or fuller of instruction, than this of Rumford; and its literary execution, by Mr. Ellis, is well worthy of the subject. The four volumes of his works comprise not only all the Count's essays, formerly published in English, but also valuable papers written by him in French and German which have been first translated for this edition. The collection has been supervised by the Rumford Committee of the American Academy of Sciences, who have grouped together in the several volumes, as far as was practicable, the papers on allied subjects: thus the scientific papers will be found chiefly in the first two volumes; descriptions of improved methods of warming and cooking occupy the third; and the greater part of the last is devoted to philanthropic essays; but this also contains the scientific papers on light. The volumes are splendidly illustrated and elegantly printed. The American Academy of Sciences could have given no worthier tribute to the fame of this man than to furnish the world with so excellent an edition of his writings.

Life-Histories of the Birds of Eastern Pennsylvania. By Thomas Gentry. In Two Volumes. Vol. I. Pp. 400. Philadelphia: The author.

This work is intended to present more fully than has been done before the habits, food, migrations, and other characteristics of the birds of Eastern Pennsylvania.

Especial attention is given to the building of nests; showing wherein they vary, and the causes for such variations.

The labor of nidification; the periods of incubation, and the part which the male takes in it; the age when the young quit their nests; the character of the sexes before and after incubation; and the food, as insects, seeds, and berries, on which the birds, old and young, depend, are carefully considered by the patient and indefatigable author.

Very much of value is thus added to our knowledge of bird-life, and what is specially important to our knowledge of the instincts and mental constitution and emotions of birds.

We look for good results from the labors of Mr. Gentry. The system of classification he adopts is the same as that of Dr. Elliott Coues in his "Key to North American Birds."

Report of the Trustees of the Harvard Museum of Comparative Zoölogy.

Gives an account of all changes and additions in the various sections of the Museum during 1875. From the report on instruction in zoölogy, it appears that during the year 1874-'75 there were eighteen students attending the lectures of Prof. McCrady. A detailed statement is made of the condition of the Agassiz Memorial Fund.

The Physiology of the Circulation in Plants, in the Lower Animals, and in Man. By J. Bell Pettigrew, M. D., F. R. S. London and New York: Macmillan. Pp. 329. Price, $4.

In this work we have what the *Lancet* justly calls "the first serious attempt at a great generalization on an avowedly difficult subject." The author has undertaken no less a task than to show that the circulation, as it takes place in plants, animals, and man, is essentially the same in kind; differing mainly in the degree of complexity attained by the organs which carry it on, and of the resulting movements of the circulating fluids.

The book opens with a brief history of the growth of the subject, from the fanciful notions held centuries ago by the Chinese that "the circulation of the vital heat and radical humors commenced at three o'clock in the morning, reached the lungs in the course of the day, and terminated in the liver at the end of twenty-four hours," up to the exact scientific demonstrations of Harvey and Malpighi. "The term 'circulation,' in the present day," says the author, "is employed in a double sense. In its wider signification it embraces the course of the nutritious juices through plants and the lower order of animals; in its more limited signification, and as applied to man and the higher orders of animated beings, it indicates the course of the blood from the heart to the capillaries, and from these back again to the heart. The word 'circulation' literally means a *flowing round*, a going and returning; and it is well to bear the original meaning in mind, as we shall find that a single circle aptly represents the circulation in most of the lower animals, a circle with one or more accessory loops, representing the circulation in the higher ones."

The circulation in plants is first described, the ascent, descent, and lateral distribution of the sap, and the forces which maintain the flow, being each fully treated. Many curious resemblances between the circulation in plants and that in animals are pointed out in this section of the work. On this point the author says: "I now proceed to a consideration of the circulation as it exists in animals; and an attentive examination of the subject not only induces me to believe that there is a striking analogy between the circulation in animals and plants, but that in animals devoid of pulsatile vessels and hearts it is in some senses identical, and traceable to the operation of the same forces."

The subject of the circulation in animals occupies the bulk of the book, that of the invertebrates, as being in some sense intermediate between plants and the higher animals, being treated first. In a number of the lowest of these no trace of a circulation has yet been detected, the nutritious fluids in such cases being supposed to pass from the alimentary canal by interstitial transudation throughout the entire body, as the sap passes into the substance of cellular plants. A step in advance is observed where, as in the polypi, medusæ, etc., the alimentary canal is of large size and ramifies in every part of the body, serving at the same time as a circulatory and alimentary apparatus. The next advance is the appearance of distinct vessels, *minus* contractile power, as in plants. Vessels possessing contractile power, but without any distinct contractile organ, are next found; and afterward the heart appears, increasing in complexity of structure along with the related organs, until its highest development is reached in the mammalia.

On the subject of the forces which give rise to the circulation in the higher animals, the author, while admitting that a large share of the work is done by the heart, argues at length in favor of the view that this organ alone is not equal to the task; and that other agencies, such as osmosis, capillary attraction, absorption, chemical affinity, etc., aid materially in the process.

To the physiological student the book is exceedingly interesting, not only for the novel views which it contains, but for the admirable way in which the author has presented the leading facts of his subject, as drawn from the whole range of living Nature. The print is good, and the illustrations, of which there are one hundred and fifty, are also well done.

### LECTURES ON SOME RECENT ADVANCES IN PHYSICAL SCIENCE. By P. G. TAIT, M. A. Pp. 337. Macmillan & Co. Price, $2.50.

THE disputes that have arisen in various quarters regarding the honor due to different investigators for working out the modern doctrines of "Energy" have been participated in by Prof. Tait, of Edinburgh, and this volume is probably due to his interest in the controversy. He was invited by a number of his friends to give a course of lectures on the chief advances made in natural philosophy since their student-days, and the author remarks that "the only special requests made to me were, that I should treat fully the modern history of energy, and that I should publish the lectures verbatim." The strictly historic part, however, is by no means the main, or the most important, feature of the work. It furnishes its method, but the book is valuable chiefly as explaining and expounding the modern doctrines of energy in a manner at once popular and thorough. No adequate exposition of these views has yet gained entrance into our text-books of physics; and a work was much needed, by a competent man, which would present the whole question in its latest aspects. The volume of Prof. Tait, though not without its defects, may be commended as meeting this want in a tolerably satisfactory manner.

### THROUGH AND THROUGH THE TROPICS. By FRANK VINCENT, Jr. New York: Harper & Brothers. Pp. 304.

THIRTY thousand miles of travel affords large opportunity for observations, and to give an account of them in a book of three hundred pages seems a hopeless task. Mr. Vincent, however, has made the attempt in this racy book, and has succeeded fairly in presenting a series of descriptions of some of the more important places visited by him, and the reader follows him with interest to the close. His chapters on the Sandwich Islands, and on the journey to High Asia, to the sacred city of the Hindoos, and to the famous Taj Mahal, are especially full of interest.

### THE EARLY LITERATURE OF CHEMISTRY. VI. By H. C. BOLTON.

THIS sixth part of Dr. Bolton's "Notes on the Early Literature of Chemistry" treats of the ancient papyrus-book on medicine discovered by Ebers at Thebes, Egypt, two or three years ago. Dr. Bolton gives the table of contents of the book with some selected passages translated out of the hieratic original.

### A Treatise on the Diseases of the Nervous System. By William A. Hammond, M. D. New York: D. Appleton & Co. Pp. 883, with 109 Illustrations. Price, $6.

The standing of this work may be inferred from the fact that it has gone to the sixth edition, and, having been out of print a year, reappears rewritten, enlarged, and much improved. Dr. Hammond has made the subject of this work a specialty, and his extensive medical practice in the department of nervous diseases can hardly fail to give much practical value to his treatise upon the subject. The work is written for medical students and the profession, but other people can collect a great deal of information from it, curious and valuable, in regard to nervous actions, conditions, and disorders.

In his preface Dr. Hammond says: "One feature I may, however, with justice claim for this work,.and that is, that it rests to a great extent on my own observation and experience, and is, therefore, no mere compilation. The reader will readily perceive that I have views of my own on every disease considered, and that I have not hesitated to express them." Obviously, the great obscurity and unsettledness of our knowledge, both of the physiology and pathology of the nervous system, offer a strong temptation to confident minds to form and promulgate positive opinions concerning them, but the same causes should enforce caution upon the student in their acceptance.

### Painters' Magazine. Monthly, pp. 40. A. G. Sullivan, Editor and Publisher.

The eighth number of the second annual volume has just been published, and presents to its readers an excellent and varied table of contents, besides some useful illustrations for the practical painter, artist, etc. The contributions are from some of the best writers of the day upon the various branches of painting. This magazine must be useful not only to the painter, but also to the architect and builder. That a better idea may be had, we give the headings of leading articles, viz.: House-Painting; Interior or Mural Decoration; Pigment and Color; Hints on Drawing; Answers to Correspondents; Railway-Car Painting, etc. Price, $1.50 per annum.

### Magnetism and Electricity. By F. Guthrie. New York: Putnams. Price, $1.50.

In this little volume, Prof. Guthrie, of the Royal School of Mines, London, presents to the general student of magnetism and electricity a very full compendium of that science. In directness of statement and clearness of expression this treatise is deserving of very high praise, and these qualities it doubtless owes to the circumstance that it is based upon the notes of the lectures delivered by the author for many years to mining students and science-teachers. The work is illustrated with over 300 woodcuts.

### Notes on Building Construction. For sale by Lippincott, Philadelphia.

This is the first of a series of three volumes, intended to assist pupils who are preparing for the examinations in building construction held annually under the direction of the Science and Art Department of the British Government. This first part treats of the points laid down as necessary for the examination in the elementary course. The subjects discussed are: Walling and arches; brickwork; masonry; carpentry; floors; partitions; timber roofs; iron roofs; slating; plumbing; cast-iron girders; joinery.

### Legal Chemistry. By A. Naquet. Pp. 178. Price, $2. New York: Van Nostrand.

The title of this work sufficiently indicates its purport, namely, the solution of chemical problems arising in the administration of justice. As a matter of course, the subject of the detection of poisons receives the most attention; but the author also describes the processes to be adopted for examining sundry alimentary and pharmaceutical substances, for examining written documents, blood-stains, etc. The translator of the work, Dr. J. P. Battershall, appends a list of books and memoirs on the subject of toxicology and the allied branches.

### Principal Characters of the Dinocerata. By Prof. O. C. Marsh.

This is a reprint from the *American Journal of Science and Art.* Besides the letter-press, the paper contains six lithographic plates giving views of the skull, dentition, jaw, feet, etc., of Dinocerata.

## PUBLICATIONS RECEIVED.

Structure and Relation of Dinichthys. By J. S. Newberry. Pp. 64. With Plates. Columbus, Ohio: Nevins & Myers.

Chemistry, Practical and Analytical. Parts 1, 2, 3, 4, 5. Philadelphia: Lippincott & Co.

Report on Vienna Bread. By E. N. Horsford. Pp. 130. Washington: Government Printing-Office.

Worcester Lyceum and Natural History Association. By N. Payne. Pp. 13.

Land and Fresh-Water Mollusca found in the vicinity of Cincinnati. Pp. 5.

Man: Palæolithic, Neolithic, etc., not inconsistent with Scripture. By Nemo. Dublin: Hodges, Foster & Co. Pp. 137. Price, five shillings.

Bulletin of the United States Geological and Geographical Survey of the Territories. Vol. II., Nos. 1 and 2. Washington: Government Printing-Office. Pp. 90 and 100.

Bulletin of the Bussey Institution. Part 5. Pp. 95

Roads, Streets, and Pavements. By Brevet Major-General Gillmore. Pp. 258. New York: Van Nostrand. Price, $2.

American Catholic Quarterly Review. Vol. I., No. 2. Pp. 190. Philadelphia: Hardy & Mahony. Price, $5 per annum.

Tansactions of the Kansas Academy of Science. Vol. IV., pp. 64. Topeka: G. W. Martin, Printer.

Geological Survey of Ohio. Paleontology, Vol. II., pp. 432, with numerous Plates; Geology, Vol. II., pp. 700, with Maps. Columbus: Nevins & Myers, State Printers.

Physics and Hydraulics of the Mississippi River. By J. B. Eads, C. E. Pp. 33. New Orleans: *Picayune* Print.

The Drift of Devon and Cornwall. By T. Belt, F. G. S. Pp. 11.

Urinary Calculus. By W. F. Westmoreland, M. D. Pp. 11. Atlanta, Georgia: Dunlop, Wynne & Co.

The "One-Rail" Railroad. By C. J. Quetil. New York: Cheap Transportation Association.

List of Skeletons and Crania in the Army Medical Museum, Washington. Pp. 52.

The Opium-Habit. By S. E. Chaillé, M. D. Pp. 9. From the *New Orleans Medical and Surgical Journal.* Also, Climatotherapy of Consumption. Same author. Pp. 16.

Michigan State Board of Health Report, 1875. Pp. 170.

Transcendentalism. By Theodore Parker. Boston: Free Religious Association. Pp. 39. Price, 10 cents.

Mechanical Construction of Water, By Captain J. E. Cole. Pp. 27. New York: E. O'Keefe, Printer.

Hospitals for the Sick and Insane. Pp. 54. Albany: Weed, Parsons & Co.

Deed of Trust of James Lick. Pp. 24.

New Orleans Price Current, 1876. Pp. 89.

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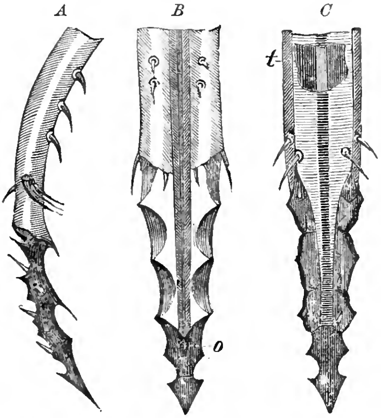
# MISCELLANY.

**A Moth that bores for its Food.**—The order of *Lepidoptera*, which includes moths and butterflies, is almost universally characterized as possessing a flexible trunk, by means of which the insects suck up the nectar of flowers. Indeed, the possession of a flexible trunk is commonly regarded as one of the distinguishing characteristics of this order. A few years ago, however, a French botanist, M. Thozet, then residing in Australia, discovered a moth (*Ophideres fullonica*) which possessed a trunk so rigid as to be able to pierce the rinds of oranges and suck their juice. Another Australian observer having since called attention to the depredations of this moth, M. J. Künckel was led to examine the trunks of *Ophideres* which had been sent to him from Australia by M. Thozet. This trunk he declares to be a perfect instrument, and says that it would be an excellent model for the making of new tools to be employed in boring holes in various materials. It resembles the barbed lance, the gimlet, and the rasp, and hence can pierce, bore, and tear, at the same time allowing liquids to pass without impediment by the internal canal. The two applied maxillæ constituting the organ terminate in a sharp triangular point, furnished with two barbs; then they become enlarged, and present on the lower surface three portions of the thread of a screw, while their sides and their upper surface are covered with short, strong spines, projecting from the centre of a depression with hard and abrupt margins. The purpose of these spines is to tear the cells of the orange pulp, as the rasp serves to open the cells of the beet-root, in order to extract sugar. The upper region of the trunk is covered below and on the sides with fine, close-set striæ, arranged in half-screws, which give it the properties of a file; the striæ are interrupted here and there by small spines of soft consistence, which serve for the perception of tactile sensations. The orifice of the canal is situated in the lower surface, below the first screw-third. All this will be seen better from the annexed figures:



TRUNK OF *Ophideres fullonica*.—*A*, in Profile; *B*, from below; *C*, from above; *t*, Interior Canal; *o*, Orifice of the Canal.

On investigation, M. Künckel has found that *all* the species of the genus *Ophideres* possess a similar terebrant trunk. This circumstance establishes a closer relationship between the *Lepidoptera*, the *Hemiptera*, and certain *Diptera* in which the maxillæ are adapted to pierce tissues.

As we learn from Prof. A. R. Grote, the group of *Noctuidæ* to which *Ophideres* belongs, called by Borkhausen *Fasciatæ*, is represented by only a few forms in Europe, but it is largely developed in the tropics of both hemispheres. The peculiar structure of the maxillæ observed in *Ophideres* has not been found in any of the North American genera of the group. In the genus *Catocala*, which is largely represented in North America, the spiral tongue or trunk is simply furnished with lateral papillæ, appearing like serratures, toward the extremity of the trunk.

**Cunning of the Adder.**—A correspondent of the Milwaukee *Sentinel* confirms Mr. Lewis's observations on the cunning of the adder (in the February number of the MONTHLY). This correspondent states that, over thirty years ago, in Leeds, Greene County, New York, his attention was one day attracted by the plaintive cry of a cat. Looking into a garden, an adder was seen near the cat. The cat seemed to be completely paralyzed by fear of the adder; she kept up the plaintive cry, as if in great distress, but did not take her eye off the serpent, or make any attempt to attack or escape. Soon the snake saw that human eyes were observing him, and he commenced to crawl slowly away. "I then," continues the writer of the narrative, "concluded to release the cat from its trouble. I took a garden-rake and put it on the snake's back, and held it without hurting it. As soon as I had the snake fast in this position, it raised its head, flattened it out, and blew, making a hissing noise, and something resembling breath or steam came from its mouth. When that was exhausted I removed the rake, and the adder turned over on its back, lying as if dead. With the rake I turned it over on its belly again, but it immediately turned on its back. This was repeated several times. At last it was taken out of the garden, laid in the road, and we all retired to watch its movements. It commenced to raise and turn its head slowly (looking about the while), until entirely on its belly, and started at full speed for a little pool of water in the road, from which it was raked out and dispatched."

**Measuring Distances by Sound.**—The Prussian correspondent of the London *Times* makes mention of an instrument devised by Major Le Boulanger, of the Belgian Artillery, which, with great accuracy, indicates the distance between two armies from the report of their guns. The moment the enemy fires a shot, the action of the report upon the "telemeter" marks the distance to a fraction. The instrument is entirely self-acting, easily kept in order, and requires no particular experience or intricate calculations to use it aright. The experiments to which it has been subjected in Prussia and in some other countries are stated to have been completely successful as regards cannon. Experiments in the rifle-grounds are still going on. Even should the invention be confined to artillery, its effect must be tremendous, considering the present deadly efficiency of fire-arms. One of its principal advantages, it is supposed, will be to enable gunners in a coast-battery to determine the position of a hostile ship—a calculation hitherto fraught with special difficulty.

**Sir John Lubbock on the Habits of Ants.**—Sir John Lubbock still continues his observations of ants, and at a recent meeting of the Linnean Society of London read a paper in which he treated—1. Of the power of intercommunication among ants; 2. Their organs of sense; 3. Their affection or regard for one another. The results are chiefly negative, contradicting many generally-received opinions. To test the ants' power of communicating information to one another, the author had a glass box for the "nest," so that he could watch what was done inside. This was placed on a pole. On the other side of the pole was a board intended as a promenade for the ants. Near to this were three pieces of glass, connected with the board by strips of paper. On one of the pieces of glass was placed a collection of food, and on the other two there was nothing. Two ants were taken and marked with spots of color, as in former observations, so that they should be readily recognized. These were both taken, one after the other, to the store of food, and were guided and taught their way to the nest. They soon learned their way to and from the nest to the food-supply, coming out of the door along the outside to the pole, around that, across the board, along the paper bridge, and so to the glass that supported the food, and so back again to the nest. Sir John Lubbock's object was to watch whether the other ants in the nest would find out the food, and, if so, to test as far as possible whether they found it from information given, or whether they tracked the scent. He devoted certain periods to watching the movements of the ants, counting the number of journeys made by his marked ants, and also recording how many untaught strangers made their way from the board along the right bridge to the food. At his first period of observation he found that, while his marked ants made forty journeys with food, nineteen strangers also came on to the bridges. Of these, two only turned to the food, eight turned to the wrong bridge, and the rest went straight on. Modifications in the arrangements of the bridges were made in different ways, while the rest of the construction was left unaltered. The observations made on different days and during periods of different duration all showed the same result.

In referring to the organs of sense, Sir John had endeavored to ascertain whether the antennæ are organs of hearing or of smell. He had tried them with all sorts of noises he could contrive, and found no results. If ants have hearing, they must be sensible to those vibrations of the air which do not affect the human ear. But he had also tried the antennæ with smells, and he found that if he put a fine camel's-hair pencil with a scent on it near one of them it shrank away, and then, if applied to the other, that also turned away. The use of the antennæ, however, still needs investigation, and Sir John hopes soon to make further observations. As regards their affection for one another, he does not doubt that an ant that dies laden with food will be cared for by its companions; but he brought forward a number of instances in which he had put ants that had suffered immersion in water for periods of from an hour to ten hours in the way of ants that were passing by, and he found almost invariably that they took no notice of their unfortunate brethren. Indeed, the exceptions in which any attention was paid were so few that Sir John said he was disposed to regard these as ants with individual feelings, which were by no means those common to the community. It is understood that the results of Sir John Lubbock's long-continued researches into the habits of bees and ants will be given to the public before long in a volume of the "International Scientific Series."

**Sea-Soundings without a Line.**—Dr. Siemens exhibited, at a recent meeting of the London Royal Society, an instrument devised by himself for ascertaining the depth of the sea. In explaining the principle of this instrument, Mr. Siemens observed that the total gravitation of the earth, as measured on its normal surface, is composed of the separate attractions of its parts, and that the attractive influence of each equal volume varies directly as its density and inversely as the square of its distance from the point of measurement. The density of sea-water being about 1.026, and that of the solid constituents composing the earth's crust about 2.763, it follows that an intervening depth of sea-water must exercise a sensible influence upon total gravitation if measured on the surface of the sea. His instrument, which he calls a bathometer, is described in the London *Times* as consisting "essentially of a vertical column of mercury, contained in a steel tube having cup-like extensions at both extremities, so as to increase the terminal area of the mercury. The lower cup is closed by means of a corrugated diaphragm of thin steel plate, and the weight of the column of mercury is balanced in the centre of the diaphragm by the elastic force derived from two carefully-tempered spiral steel springs of the same length as the mercury-column. One of the peculiarities of this mechanical arrangement is, that it is parathermal, the diminishing elastic force of the springs with rise of temperature being compensated by a similar decrease of potential of the mercury-column, which decrease depends upon the proportions given to the areas of the steel tube and its cup-like extensions."

The instrument is suspended in such a manner as to retain the vertical position, notwithstanding the motion of the ship, and the vertical oscillations of the mercury are almost entirely prevented by a local contraction of the mercury-column to a very small orifice. The reading of the instrument is effected by means of electrical contact, which is established between the end of a micrometer-screw and the centre of the elastic diaphragm. The pitch of the screw and the divisions in the rim are so proportioned that each division represents the diminution of gravity due to one fathom of depth. Actual experiment has shown the apparatus to be very reliable.

**Formation of Mountain-Chains.**—This subject is considered by Prof. Joseph Le Conte in the April number of the *American Journal of Science*, in which interesting facts are presented, the results of observations made by the author in the Coast Range of California. He finds that the actual length of the folded strata is about two and a half to three times the horizontal distance through the mountains. It thus appears that from fifteen to eighteen miles of strata, that is, of original sea-bottom, has been crushed or mashed into six miles, with "corresponding up-swelling of the whole mass."

This diminution of distance, according to the theory of Prof. Le Conte, has not arisen from *folding* of the strata, but by *mashing* of them by horizontal pressure.

From the flattened and elongated form of little nodules of clay found in some of the strata, he concludes that their elongation vertically exactly correlates their shortening horizontally, and that the one is to the other as two and a half or three is to one. It thus appears that in the compression of the beds their constituent particles underwent a change of form corresponding with the conditions of the pressure.

These clay pellets or nodules are supposed to have been formed on the bottom of gently-flowing streams, are a part of the original sedimentary beds, and are the same in character as those which form greenish spots in slate, as described by Prof. Tyndall.

It will be seen that, in accounting for the elevation of mountain-chains, Prof. Le Conte differs from Prof. Dana in this: that while they agree that mountain-chains are formed by yielding of the earth's crust, Prof. Dana attaches importance chiefly to the bending and plication of it, Prof. Le Conte to the crushing of it. He says, "I am satisfied that Prof. Dana greatly underestimates the amount of elevation by simple mashing as compared with folding."

**Brain-Weight and Mental Power.**—Great weight of brain is commonly regarded as evidence of great cerebral power. That this conclusion, however, is erroneous, is shown by Dr. Robert Lawson, who, in the *Lancet*, compares the brain-weights of some of the great men of modern times with the brain-weights of lunatics who died in the West Riding Asylum. He gives the following instructive table:

| | | Ounces. | | Ounces. |
|---|---|---|---|---|
| Brain-weight of | Dr. Chalmers. . . | 53 | Lunatic | 55 |
| " | Daniel Webster. . | 53.5 | " | 58 |
| " | Sir J. Y. Simpson | 54 | " | 55.5 |
| " | Goodsir . . . . . . . . . | 57.5 | " | 59.5 |
| " | Abercrombie . . . . | 63 | " | 60.5 |
| " | Cuvier . . . . . . . . . | 64 | " | 61 |

It will be observed that only Abercrombie and Cuvier surpass in weight of brain the inmates of the asylum. One of these lunatics, he whose brain weighed 61 ounces, was seventy-one years of age when he died; when he was forty-five, his brain probably weighed not less than 64 ounces, thus equaling in weight the brain of the great Cuvier, and exceeding that of Daniel Webster by 20 per cent. From all this it follows that great weight of brain is not in itself a conclusive evidence of great intellect.

From this comparison of brain-weights, Dr. Lawson passes to the consideration of the relations between genius and insanity. "Every day," he says, "the observation of the poet, that great wit is nearly allied to madness, gains a wider and more practical acceptance. So much is this the case that Dr. Wilks ventures to make the statement that it is probably the insane element which imparts what we call genius to the human race, the true celestial fire. And though it is fearful to think of the propagation of a race tainted with insanity, yet it does not follow that an infusion of the insane blood may not be desirable. Dr. Maudsley holds the same opinion."

**Preservation of Zoölogical Specimens.**—Last summer, Profs. Verrill and Rice, of Yale College, made a number of experiments to ascertain the effects of various chemical preparations upon marine invertebrates, the objects being to improve existing methods of preserving specimens and to ascertain the best means of killing in an expanded state species which ordinarily contract very much when put directly into alcohol. The results are given in the *American Journal of Science*, by Prof. Verrill, who says that several very fine preparations of *Actiniæ* in a state of nearly perfect expansion were made by slowly adding a concentrated solution of picric acid to a small quantity of sea-water in which they had been allowed to expand. When fairly dead, they were transferred to a pure saturated solution of the acid, and allowed to remain from one to three hours. They were then placed in alcohol for permanent preservation. The alcohol should be renewed after a day or two, and this should be repeated until all the water has been absorbed from the specimen. Hydroids and most kinds of jelly-fishes can be easily preserved in the same way. Even delicate *Ctenophoræ* can be thus preserved so as to make fair specimens. The experiments were made with the view of finding some poison that will kill mollusks, especially gasteropods, in a fully-extended state, but the results were negative; at least no method was discovered that is more generally successful than that of allowing them to suffocate in stale sea-water, through excess of carbonic acid and deficiency of oxygen.

**Improvement of the Steam-Engine.**—In giving testimony before the Government Commissioners on the Advancement of Science in Great Britain, Mr. Anderson, superintendent of machinery at Woolwich, spoke of Joule's experiments on the conservation of energy as of immense value and as being an example of what government should do for the common good. Joule had made engineers thoroughly dissatisfied with their present knowledge as to what they can do with steam. "I believe," he continued, "that what Joule did will do more for this country than even what James Watt did. The part that James Watt took was very great, and the world gives him full credit for it; but the world is scarcely willing to give credit to Joule. Engineers know that the best steam-engine is not doing one-sixth of the work which it ought to do and can do. That is a sad state of matters to be in when we know that we are so far wrong, but yet no one will go to the trouble of going to the end of the question so as to improve the steam-engine as it might be done."

**Underground Forests in the Thames Valley.**—An interesting geological discovery, as we learn from *Nature*, was recently made during excavations for a new tidal basin at the Surrey Commercial Docks, London. On penetrating some six feet below the surface, the workmen everywhere came across a subterranean forest-bed, consisting of peat with trunks of trees, for the most part still standing erect. All are of species still inhabiting Britain; the oak, alder, and willow, are apparently most abundant. The trees are not mineralized, but retain their vegetable character, except that they are thoroughly saturated with water. In the peat are found bones of the great fossil ox. Fresh-water shells are also found. No doubt is entertained that the bed thus exposed is a continuation of the old buried forest which has been brought to light at various other localities on both sides of the Thames. In each case the forest-bed is found buried beneath the marsh-clay, showing that the land has sunk below the tidal level since the forest flourished.

**The Medication of Infants.**—From experiments made by Dr. Lewald it appears that sundry medicines are most advantageously introduced into the system of an infant through the mother's milk. Thus of iron a larger quantity can be administered to the infant in this way than by any other means. Bismuth, however, is eliminated in the milk only in very small quantity. Iodine does not appear in the milk until ninety-six hours after taking it; iodide of potassium appears four hours after ingestion, and continues to be eliminated for eleven days. Arsenic appears in the milk at the end of seventeen hours, and continues for at least forty hours. Oxide of zinc, though one of the most insoluble preparations, is eliminated by the milk; it disappears sooner than iron. The elimination of antimony is an undeniable fact, and it is well to bear this in mind during the period of nursing; the same holds true in regard to mercurial preparations. That alcohol and narcotics are eliminated by the milk has not been demonstrated. Sulphate of quinine is eliminated very easily, and a child suffering from intermittent fever was cured by administering quinine to the nurse.

## NOTES.

The printing-press at which Benjamin Franklin worked in London will be exhibited at Philadelphia. This press was at one time the property of Harrild & Sons, of London, but in 1841 they allowed it to be forwarded to Philadelphia. By way of acknowledgment, a sum of money was to be handed over to the Printers' Pension Corporation, for the purpose of founding a pension for an aged printer. This has never been done, and hence Franklin's press by right belongs to Messrs. Harrild, and should appear at the Centennial Exhibition as an English and not an American exhibit.

In the "Annual of Natural Science," of Würtemberg, Otto Hahn has an elaborate review of the *Eozoön Canadense* question. This article, which is very long, is published in the *Annals and Magazine of Natural History*, for April. The author, after an examination of the geological, the mineralogical, and the zoölogical facts, pronounces the so-called eozoon structures to be purely mineral in their origin.

In replying to Tyndall, Dr. Bastian cites a number of investigators as supporting his views on biogenesis. Among the authorities thus quoted are E. Ray Lankester and Dr. Pode; but the former of these two gentlemen now writes to *Nature*, saying that their (i. e., Lankester's and Pode's) results "conclusively and categorically contradict the particular assertions contained in Dr. Bastian's book, 'The Beginnings of Life,' into the truth of which they set themselves to inquire."

Specimens of paper and cardboard made from peat were recently presented to the Berlin Polytechnic Association by Herr Veyt-Meyer. The paper and cardboard were very firm, and the latter was so thick that it might be planed and polished. Paper made of peat alone is like that made from wood or straw; but only fifteen per cent. of rags is needed to give it consistence. A large factory for the manufacture of peat paper is to be established in Prussia.

In order to act intelligently against the cotton-worm, Southern planters are advised by Prof. A. R. Grote to act in concert. He further recommends that, whatever agent is employed to destroy the worm, be used against the first brood that appears in the locality, so as to prevent its spreading farther. It is highly desirable that the life-history and habits of such insect-pests should be thoroughly studied, with a view to their extermination.

Prof. Benjamin Silliman, of Yale College, has patented a process for giving resonance to sundry alloys, such as britannia metal, pewter, etc., which commonly give only a dull sound when struck. According to the *Engineering and Mining Journal*, the process consists in submitting articles made of these alloys to the action of a certain degree of temperature, just below their melting-point, for a short time, in a bath of oil or paraffine. The theory of the process appears to turn upon a rearrangement, perhaps a crystallization, of the molecules.

The Phylloxera Commission, appointed by the Paris Academy of Science, to award the Government prize of 300,000 francs for the discovery of an effectual means of destroying the *Phylloxera*, has reported that none of the specifics submitted to them are entitled to the prize.

Dr. Ewald records, in *Reichert's Archiv*, an instance of the production of a hydrocarbon gas in the stomach of a man suffering from chronic gastritis. The man, one day, while lighting a cigar, was surprised to see his breath take fire, and burn with a yellow flame. Dr. Ewald afterward analyzed some of this gas, and found it to consist of hydrogen, oxygen, nitrogen, carbonic acid, and a considerable portion (about ten per cent.) of marsh gas.

About ten per cent. of the Cape diamonds are of first quality, fifteen per cent. of second, twenty of third. The remainder are employed for cutting diamonds, and for the numerous applications of this gem in the arts. It is estimated that the value of the diamonds found at the Cape from March, 1867, to the present time exceeds £12,000,000.

Dr. Richardson, of London, cites the high death-rate of innkeepers, publicans, and the like, as evidence of the fatal effects of intoxicating drink. In London the mortality of all males is 2.012 per cent. annually; that of publicans, 3.466 per cent. In England, exclusive of London, the mortality of all males is 1.182 per cent. annually; of publicans 3.163 per cent. It is a striking fact that the death-rate in this class is higher than in any other class of male occupations named in the census, save one—the hackney-coachman.

Salicylic acid has been used with good results in Germany, in the treatment of recent superficial gangrenous sores, the method being to apply a thin layer of powdered salicylic acid on the surface of the sore, covering it then with wadding.

Experiments lately made in France show that air laden with coal-dust is highly explosive. Several cases of explosion in coal-mines have been traced to the action of suspended coal-dust when no fire-damp was present.

The practice of *scalping* is not peculiar to the American aborigines. Southall, in his "Recent Origin of Man," quotes from Herodotus to show that the Scythians used to scalp their fallen enemies. In the present time the wild tribes of Northeastern Bengal use the scalping-knife.

An expedition under the leadership of Prof. Nordenskiöld will start next summer to explore a commercial route from Northern Russia to Behring Strait. Funds have also been contributed toward the cost of another expedition to explore the gulf of Obi and the sea-route between Archangel and the great rivers of Siberia.

Edmund A. Parkes, M. D., F. R. S., Professor of Military Hygiene in the Army Medical School at Netley, England, died March 15th, at the age of fifty-six years. During the Crimean War he was selected by Government to organize and conduct a hospital, and on his return to England was appointed to the chair of Hygiene at Netley. His annual contributions on hygiene were for many years, perhaps the most valuable feature of the blue-books of the War Department. He was a very successful teacher, and a frequent contributor to the medical press, and to the "Transactions" of scientific bodies. His "Manual of Practical Hygiene" has reached a fourth edition.

Died, March 29th, Dr. Henry Letheby, for many years lecturer on chemistry and toxicology in the London Hospital, and chemical analyst of the city of London. He was the author of a number of papers on sanitary and chemical subjects, published in sundry medical journals. His work on "Food" was republished in this country three years ago. At the time of his death he was sixty years of age.

Nearly all the amber of commerce comes from Eastern Prussia, where it is obtained by dredging the bottom of the sea just off the coast. It was recently discovered that amber occurs in a deposit called the "blue earth." It has been supposed that this deposit extends for some distance inland, and a shaft was recently sunk to determine this point. At the depth of 140 feet there was found a stratum of "blue earth" without amber and two feet in thickness; then came another stratum five feet thick, which was rich in amber.

There are few who do not remember the childish wonder they once felt at hearing the resonance produced by placing a sea-shell to the ear, an effect which fancy has likened to "the roar of the sea." This is caused by the hollow form of the shell and its polished surface, enabling it to receive and return the beatings of all sounds that chance to be trembling in the air.—*Public Opinion*.

ALEXANDER BAIN.

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# THE MECHANICAL ACTION OF LIGHT.[1]

By WILLIAM CROOKES, F. R. S.

TO generate motion has been found a characteristic common, with one exception, to all the phases of physical force. We hold the bulb of a thermometer in our hands, and the mercury expands in bulk, and, rising along the scale, indicates the increase of heat it has received. We heat water, and it is converted into steam, and moves our machinery, our carriages, and our iron-clads. We bring a loadstone near a number of iron-filings, and they move toward it, arranging themselves in peculiar and intricate lines; or we bring a piece of iron near a magnetic needle, and we find it turned away from its ordinary position. We rub a piece of glass with silk, thus throwing it into a state of electrical excitement, and we find that bits of paper or thread fly toward it, and are, in a few moments, repelled again. If we remove the supports from a mass of matter it falls, the influence of gravitation being here most plainly expressed in motion, as shown in clocks and water-mills. If we fix pieces of paper upon a stretched string, and then sound a musical note near it, we find certain of the papers projected from their places. Latterly the so-called "sensitive flames," which are violently agitated by certain musical notes, have become well known as instances of the conversion of sound into motion. How readily chemical force undergoes the same transformation is manifested in such catastrophes as those of Bremerhaven, in the recent deplorable coal-mine explosions, and indeed in every discharge of a gun.

But light, in some respects the highest of the powers of Nature, has not been hitherto found capable of direct conversion into motion, and such an exception cannot but be regarded as a singular anomaly.

This anomaly the researches which I am about to bring before you

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[1] A lecture delivered at the Royal Institution.

have now removed; and, like the other forms of force, light is found to be capable of direct conversion into motion, and of being—like heat, electricity, magnetism, sound, gravitation, and chemical action—most delicately and accurately measured by the amount of motion thus produced.

My research arose from the study of an anomaly.

It is well known to scientific men that bodies appear to weigh less when they are hot than when they are cold; the explanation given being that the ascending currents of hot air buoy up the body, so to speak. Wishing to get rid of this and other interfering actions of the air during a research on the atomic weight of thallium, I had a balance constructed in which I could weigh in a vacuum. I still, indeed, found my apparatus less heavy when hot than when cold. The obvious explanations were evidently not the true ones; *obvious* explanations seldom are true ones, for simplicity is not a characteristic of Nature.

An unknown disturbing cause was interfering, and the endeavor to find the clew to the apparent anomaly has led to the discovery of the mechanical action of light.

I was long troubled by the apparent lawlessness of the actions I obtained. By gradually increasing the delicacy of my apparatus I could easily get certain results of motion when hot bodies were brought near them, but sometimes it was one of attraction, at others of repulsion, while occasionally no movement whatever was produced.

I will try to reproduce these phenomena in this apparatus (Fig. 1). Here are two glass bulbs, each containing a bar of pith about three inches long and half an inch thick, suspended horizontally by a long fibre of cocoon silk. I bring a hot glass rod, or a candle, toward one of them, and you see that the pith is gradually attracted, following the candle as I move it round the bulb. That seems a very definite fact; but look at the action in the other bulb. I bring the candle, or a hot glass rod, near the other bar of pith, and it is strongly *repelled* by it, much more strongly than it was attracted in the first instance.

Here, again, is a third fact. I bring a piece of ice near the pith-bar which has just been repelled by the hot rod, and it is attracted, and follows the rod round as a magnetic needle follows a piece of iron.

The repulsion by radiation is the key-note of these researches. The movement of a small bar of pith is not very distinct, except to those near, and I wish to make this repulsion evident to all. I have therefore arranged a piece of apparatus by which it can be seen by all present. I will, by means of the electric light, project an image of a pendulum suspended *in vacuo* on the screen. You see that the approach of a candle gives the bob a veritable push, and, by alternately obscuring and uncovering the light, I can make the pendulum beat time to my movements.

What, then, is the cause of the contradictory action in these two bulbs—attraction in one, and repulsion in the other? It can be explained in a few words. Attraction takes place when air is present, and repulsion when air is absent.

Neutrality, or no movement, is produced when the vacuum is insufficient. A minute trace of air in the apparatus interferes most materially with the repulsion, and for a long time I was unaware of the powerful action produced by radiation in a "perfect" vacuum.

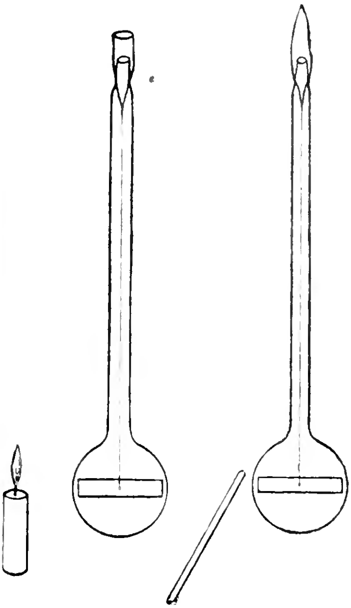

FIG. 1.

It is not at first sight obvious how ice or a cold body can produce the opposite effect to heat. The law of exchanges, however, explains this perfectly. The pith-bar and the whole of the surrounding bodies are incessantly exchanging heat-rays; and under ordinary circumstances the income and expenditure of heat are in equilibrium. Let me draw your attention to the diagram (Fig. 2), illustrating what takes place when I bring a piece of ice near the apparatus. The centre circle represents my piece of pith; the arrows show the influx and efflux of heat. A piece of ice brought near cuts off the influx of heat from one side, and therefore allows an excess of heat to fall on the pith from the opposite side. Attraction by a cold body is therefore seen to be only repulsion by the radiation from the opposite side of the room.

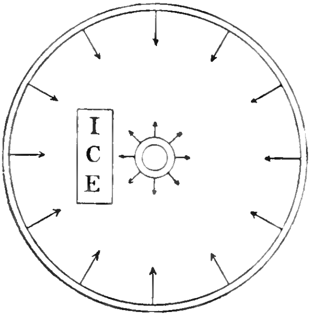

FIG. 2.

The later developments of this research have demanded the utmost refinement of apparatus. Everything has to be conducted in glass vessels, and these must be blown together till they make one piece, for none but fused joints are admissible. In an investigation depending for its successful prosecution on manipulative dexterity, I have been fortunate in having the assistance of my friend Mr. Charles Gimingham. All the apparatus you see before you are the fruits of his skillful manipulation, and I now want to draw your attention to what I think is a masterpiece of glass-working—the pump which enables me so readily to produce a vacuum unattainable by ordinary means.

The pump here at work is a modification of the Sprengel pump, but it contains two or three valuable improvements. I cannot attempt to describe the whole of the arrangements, but I will rapidly run over them as illuminated by the electric light. It has a triple-fall tube in which the mercury is carried down, thus exhausting with threefold rapidity; it has Dr. McLeod's beautiful arrangement for measuring the residual gas; it has gauges in all directions, and a small radiometer attached to it to tell the amount of exhaustion that I get in any experiments; it has a contrivance for admitting oil of vitriol into the tubes without interfering with the progress of the exhaustion, and it is provided with a whole series of most ingenious vacuum-taps devised by Mr. Gimingham. The exhaustion produced in this pump is such that a current of electricity from an induction-coil will not pass across the vacuum. This pump is now exhausting a torsion-balance, which will be described presently. Another pump, of a similar kind but less complicated, is exhausting an apparatus which has enabled me to pass from the mere exhibition of the phenomena to the obtaining of quantitative measurements.

A certain amount of force is exerted when a ray of light or heat falls on the suspended pith, and I wished to ascertain—

1. What were the actual rays—invisible heat, luminous, or ultra-violet—which caused this action?

2. What influence had the color of the surface on the action?

3. Was the amount of action in direct proportion to the amount of radiation?

4. What was the amount of force exerted by radiation?

I required an apparatus which would be easily moved by the impact of light on it, but which would readily return to zero, so that measurements might be obtained of the force exerted when different amounts of light acted on it. At first I made an apparatus on the principle of Zöllner's horizontal pendulum. For a reason that will be explained presently, I am unable to show you the apparatus at work, but the principle of it is shown in the diagram (Fig. 3). The pendulum represented by this horizontal line has a weight at the end. It is supported on two fibres of glass, one stretched upward and the other stretched downward, both firmly fastened at the ends, and also attached to the horizontal rod (as shown in the figure) at points near together, but not quite opposite to one another.

It is evident that if there is a certain amount of pull upon each of these fibres, and that the pull can be so adjusted as to counteract the weight at the end and keep it horizontal, the nearer the beam approaches the horizontal line the slower its rate of oscillation. If I relax the tension, by throwing the horizontal beam downward, I get a more rapid oscillation sideways. If I turn the leveling-screw so as to raise the beam and weight, the nearer it approaches the horizontal position the slower the oscillation becomes, and the more delicate is the instrument. Here is the actual apparatus that I tried to work with. The weight at the end is a piece of pith; in the centre is a glass mirror, on which to throw a ray of light, so as to enable me to see the movements by a luminous index. The instrument, inclosed in glass and exhausted of air, was mounted on a stand with leveling-screws, and with it I tried the action of a ray of light falling on the pith. I found that I could get any amount of sensitiveness that I liked; but it was not only sensitive to the impact of a ray of light, it was immeasurably more so to a change of horizontality. It was, in fact, too delicate for me to work with. The slightest elevation of one end of the instrument altered the sensitiveness, or the position of the zero-point, to such a degree that it was impossible to try any experiments with it in such a place as London. A person stepping from one room to another altered the position of the centre of gravity of the house. If I walked from one side of my own laboratory to the other, I tilted the house over sufficiently to upset the equilibrium of the apparatus. Children playing in the street disturbed it. Prof. Rood, who has worked with an apparatus of this kind in America, finds that an elevation of its side equal to $\frac{1}{36000000}$ part of an inch is sufficient to be shown on the instrument. It was therefore out of the question to use an instrument of this construction, so I tried another form (shown in Fig. 4), in which a fine glass beam, having disks of pith at each end, is suspended horizontally by a fine glass fibre, the whole being sealed up in glass and perfectly exhausted. To the centre of oscillation a glass mirror is attached.

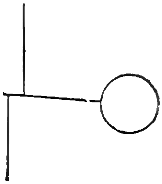

FIG. 3.

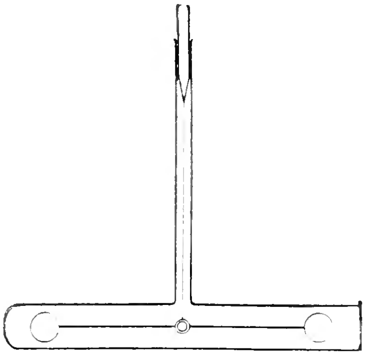

FIG. 4.

Now, a glass fibre has the property of always coming back to zero when it is twisted out of its position. It is almost, if not quite, a perfectly elastic body. I will show this by a simple experiment. This is a long glass fibre hanging vertically, and having an horizontal bar suspended on it. I hold the bar, and turn it half round; it swings backward and forward for a few times, but it quickly comes back to its original position. However much twist, however much torsion, may be put on this, it always returns ultimately to the same position. I have twisted glass fibres round and kept them in a permanent state of twist more than a hundred complete revolutions, and they always came back accurately to zero. The principle of an instrument that I shall describe farther on depends entirely on this property of glass.

Instead of using silk to suspend the torsion-beam with, I employ a fibre of glass, drawn out very fine before the blow-pipe. A thread of glass of less than the thousandth of an inch in thickness is wonderfully strong, of great stiffness, and of perfect elasticity, so that, however much it is twisted round short of the breaking-point, it untwists itself perfectly when liberated. The advantage of using glass fibres for suspending my beam is, therefore, that it always returns accurately to zero after having tried an experiment, while I can get any desired amount of sensitiveness by drawing out the glass fibre sufficiently fine.

Here, then, is the torsion apparatus sealed on to a Sprengel pump. You will easily understand the construction by reference to the diagram (Fig. 4). It consists of an horizontal beam suspended by a glass fibre, and having disks of pith at each end coated with lampblack. The whole is inclosed in a glass case, made of tubes blown together, and by means of the pump the air is entirely removed. In the centre of the horizontal beam is a silvered mirror, and a ray from the electric light is reflected from it on to a scale in front, where it is visible as a small circular spot of light. It is evident that an angular movement of the torsion-beam will cause the spot of light to move to the right or to the left along the scale. I will first show you the wonderful sensitiveness of the apparatus. I simply place my finger near the pith-disk at one end, and the warmth is quite sufficient to drive the spot of light several inches along the scale. It has now returned to zero, and I place a candle near it. The spot of light flies off the scale. I now bring the candle near it alternately from one side to the other, and you see how perfectly it obeys the force of the candle. I think the movement is almost better seen without the screen than with it. The fog, which has been so great a detriment to every one else, is rather in my favor, for it shows the luminous index like a solid bar of light swaying to and fro across the room. The warmth of my finger, or the radiation from a candle, is therefore seen to drive the pith-disk away. Here is a lump of ice, and on bringing it near one of the disks the luminous index promptly shows a movement of apparent attraction.

With this apparatus I have tried many experiments, and among others I endeavored to answer the question, "Is it light, or is it heat, that produces the movement?"—for that is a question that is asked me by almost every one; and a good many appear to think that, if the motion can be explained by an action of heat, all the novelty and the importance of the discovery vanish. Now, this question of light or heat is one I cannot answer, and I think that when I have explained the reason you will agree with me that it is unanswerable. There is no physical difference between light and heat. Here is a diagram of the visible spectrum (Fig. 5). The spectrum, as scientific men understand it, extends from an indefinite distance beyond the red to an indefinite distance beyond the violet. We do not know how far it would extend one way or the other if no absorbing media were present; but, by what we may call a physiological accident, the human eye is sensitive to a portion of the spectrum situated between the line *A* in the red to about the line *H* in the violet. But this is not a physical difference between the luminous and non-luminous parts of the spectrum; it is only a physiological difference. Now, the part at the red end of the spectrum possesses, in the greatest degree, the property of causing the sensation of warmth, and of dilating the mercury in a thermometer, and of doing other things which are conveniently classed among the effects of *heat;* the centre part affects the eye, and is therefore called *light;* while the part at the other end of the spectrum has the greatest energy in producing *chemical action.* But it must not be forgotten that any ray of the spectrum, from whatever part it is selected, will produce all these physical actions in more or less degree. A ray here, at the letter *C* for instance in the orange, if concentrated on the bulb of a thermometer, will cause the mercury to dilate, and thus show the presence of *heat;* if concentrated on my hand I feel *warmth;* if I throw it on the face of a thermo-pile it will produce a current of *electricity;* if I throw it upon a sensitive photographic plate it will produce *chemical action;* and if I throw it upon the instrument I have just described it will produce *motion.* What, then, am I to call that ray? Is it light, heat, electricity, chemical action, or motion? It is neither. All these actions are inseparable

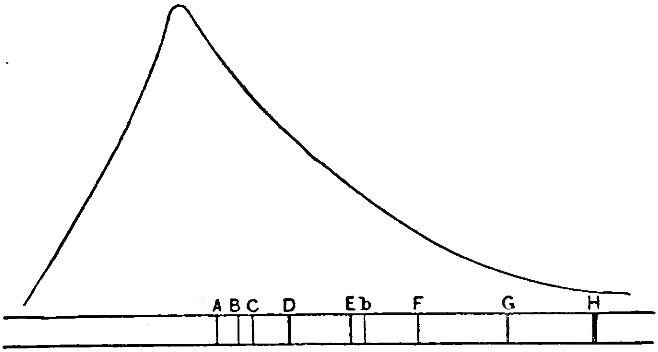

FIG. 5.

attributes of the ray of that particular wave-length, and are not evidences of separate identities. I can no more split that ray up into five or six different rays, each having different properties, than I can split up the element iron, for instance, into other elements, one possessing the specific gravity of iron, another its magnetic properties, a third its chemical properties, a fourth its conducting power for heat, and so on. A ray of light of a definite refrangibility is one and indivisible, just as an element is, and these different properties of the ray are mere functions of that refrangibility, and inseparable from it. Therefore when I tell you that a ray in the ultra-red pushes the instrument with a force of one hundred, and a ray in the most luminous part has a dynamic value of about half that, it must be understood that the latter action is not due to heat-rays which accompany the luminous rays, but that the action is one purely due to the wave-length and the refrangibility of the ray employed. You now understand why it is that I cannot give a definite answer to the question, "Is it heat or is it light that produces these movements?" There is no physical difference between heat and light; so, to avoid confusion, I call the total bundle of rays which come from a candle or the sun, *radiation*.

I found, by throwing the pure rays of the spectrum one after the other upon this apparatus, that I could obtain a very definite answer to my first question, "What are the actual rays which cause this action?"

The apparatus was fitted up in a room specially devoted to it, and was protected on all sides, except where the rays of light had to pass, with cotton-wool and large bottles of water. A heliostat reflected a beam of sunlight in a constant direction, and it was received on an appropriate arrangement of slit, lenses, prisms, etc., for projecting a pure spectrum. Results were obtained in the months of July, August, and September; and they are given in the figure (Fig. 5) graphically as a curve, the maximum being in the ultra-red and the minimum in the ultra-violet. Taking the maximum at 100, the following are the mechanical values of the different colors of the spectrum:

| | |
|---|---|
| Ultra-red | 100 |
| Extreme red | 85 |
| Red | 73 |
| Orange | 66 |
| Yellow | 57 |
| Green | 41 |
| Blue | 22 |
| Indigo | 8½ |
| Violet | 6 |
| Ultra-violet | 5 |

A comparison of these figures is a sufficient proof that the mechanical action of radiation is as much a function of the luminous rays as it is of the dark heat-rays.

The second question—namely, "What influence has the color of the surface on the action?" has also been solved by this apparatus.

In order to obtain comparative results between disks of pith coated with lampblack and with other substances, another torsion apparatus was constructed, in which six disks *in vacuo* could be exposed one after the other to a standard light. One disk always being lampblacked pith, the other disks could be changed so as to get comparisons of action. Calling the action of radiation from a candle on the lampblacked disk 100, the following are the proportions obtained:

| | |
|---|---|
| Lampblacked pith | 100 |
| Iodide of palladium | 87.3 |
| Precipitated silver | 56 |
| Amorphous phosphorus | 40 |
| Sulphate of baryta | 37 |
| Milk of sulphur | 31 |
| Red oxide of iron | 28 |
| Scarlet iodide of mercury and copper | 22 |
| Lampblacked silver | 18 |
| White pith | 18 |
| Carbonate of lead | 13 |
| Rock-salt | 6.5 |
| Glass | 6.5 |

This table gives important information on many points: one more especially—the action of radiation on lampblacked pith is five and a half times what it is on plain pith. A bar like those used in my first experiment, having one-half black and one-half white, exposed to a broad beam of radiation, will be pushed with five and a half times more strength on the black than on the white half, and if freely suspended will set at an angle greater or less according to the intensity of the radiation falling on it.

This suggests the employment of such a bar as a photometer, and I have accordingly made an instrument on this principle; its construction is shown in the diagram (Fig. 6). It consists of a flat bar of pith, *A*, half black and half white, suspended horizontally in a bulb by means of a long silk fibre. A reflecting mirror, *B*, and small magnet, *C*, are fastened to the pith, and a controlling magnet, *D*, is fastened outside so that it can slide up and down the tube, and thus increase or diminish sensitiveness. The whole is completely exhausted and then inclosed in a box lined with black velvet, with apertures for the rays of light to pass in and out. A ray of light from a lamp, *F*, reflected from the mirror, *B*, to a graduated scale, *G*, shows the movements of the pith-bar.

The instrument fitted up for a photometric experiment is in front of me on the table. A beam from the electric light falls on the little mirror, and is thence reflected back to the screen, where it forms a spot of light, the displacement of which to the right or the left shows the movement of the pith-bar. One end of the bar is blacked on each side, the other end being left plain. I have two candles, *E E*, each twelve inches off the pith-bar, one on each side of it. When I remove the screens, *H H*, the candle on one side will give the pith a push in one direction, and the candle on the other side will give the pith a push in the opposite direction, and as they are the same distance off they will neutralize each other, and the spot of light will not move. I now take the two screens away: each candle is pushing the

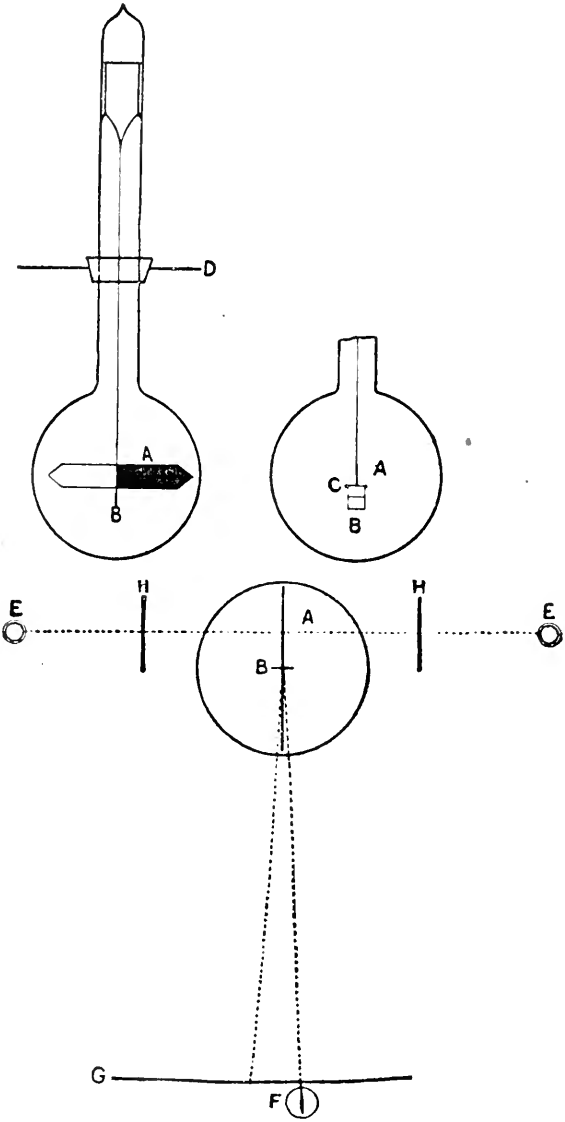

Fig. 6.

pith equally in opposite directions, and the luminous index remains at zero. When, however, I cut one candle off, the candle on the opposite side exerts its full influence, and the index flies to one end of the scale. I cut the other one off and obscure the first, and the spot of light flies to the other side. I obscure them both, and the index comes quickly to zero. I remove the screens simultaneously, and the index does not move.

I will retain one candle 12 inches off, and put two candles on the other side 17 inches off. On removing the screens you see the index does not move from zero. Now the square of 12 is 144, and the square of 17 is 289. Twice 144 is 288. The light of these candles, therefore, is as 288 to 289. They therefore balance each other as nearly as possible. Similarly I can balance a gaslight against a candle. I have a small gas-burner here, which I place 28 inches off on one side, and you see it balances the candle 12 inches off. These experiments show how conveniently and accurately this instrument can be used as a photometer. By balancing a standard candle on one side against any source of light on the other, the value of the latter in terms of a candle is readily shown; thus in the last experiment the standard candle 12 inches off is balanced by a gas-flame 28 inches off. The lights are, therefore, in the proportion of $12^2$ to $28^2$, or as 1 to 5.4. The gas-burner is, therefore, equal to about five and a half candles.

In practical work on photometry it is often required to ascertain the value of gas. Gas is spoken of commercially as of so many candle-power. There is a certain "standard" candle which is supposed to be made invariable by act of Parliament. I have worked a great deal with these standard candles, and I find them to be among the most variable things in the world. They never burn with the same luminosity from one hour to the other, and no two candles are alike. I can now, however, easily get over this difficulty. I place a "standard" candle at such a distance from the apparatus that it gives a deflection of 100° on the scale. If it is poorer than the standard, I bring it nearer; if better, I put it farther off. Indeed, any candle may be taken; and if it be placed at such a distance from the apparatus that it will give a uniform deflection, say, of 100 divisions, the standard can be reproduced at any subsequent time; and the burning of the candle may be tested during the photometric experiments by taking the deflection it causes from time to time, and altering its distance, if needed, to keep the deflection at 100 divisions. The gaslight to be tested is placed at such a distance on the opposite side of the pith-bar that it exactly balances the candle. Then, by squaring the distances, I get the exact proportion between the gas and the candle.

Before this instrument can be used as a photometer or light-measurer, means must be taken to cut off from it all those rays coming from the candle or gas which are not actually luminous. A reference to the spectrum diagram (Fig. 5) will show that at each end of the colored rays there is a large space inactive, as far as the eye is concerned, but active in respect to the production of motion—strongly so at the red end, less strong at the violet end. Before the instrument can be used to measure luminosity, these rays must be cut off. We buy gas for the light that it gives, not for the heat that it evolves on burning, and it would therefore never do to measure the heat and pay for it as light.

It has been found that a clear plate of alum, while letting all the light through, is almost if not quite opaque to the heating rays below the red. A solution of alum in water is almost as effective as a crystal of alum; if, therefore, I place in front of the instrument glass cells containing an aqueous solution of alum, the dark heat-rays are filtered off.

But the ultra-violet rays still pass through, and to cut these off I dissolve in the alum-solution a quantity of sulphate of quinine. This body has the property of cutting off the ultra-violet rays from a point between the lines *G* and *H*. A combination of alum and sulphate of quinine, therefore, limits the action to those rays which affect the human eye, and the instrument, such as you see it before you, becomes a true photometer.

This instrument, when its sensitiveness is not deadened by the powerful control magnet I am obliged to keep near it for these experiments, is wonderfully sensible to light. In my own laboratory, a candle thirty-six feet off produces a decided movement, and the motion of the index increases inversely with the square of the distance, thus answering the third question, "Is the amount of action in direct proportion to the amount of radiation?"

The experimental observations and the numbers which are required by the theoretical diminution of light with the square of the distance are sufficiently close, as the following figures show:

| | | | | |
|---|---|---|---|---|
| Candle | 6 | feet off gives a | deflection of | 218·0° |
| " | 12 | " | " | 54.0° |
| " | 18 | " | " | 24.5° |
| " | 24 | " | " | 13.0° |
| " | 10 | " | " | 77.0° |
| " | 20 | " | " | 19.0° |
| " | 30 | " | " | 8.5° |

The effect of two candles side by side is practically double, and of three candles three times that of one candle.

In the instrument just described, the candle acts on a pith-bar, one end of which is blacked on each side. But suppose I black the bar on alternate halves, and place a light near it sufficiently strong to drive the bar half round. The light will now have presented to it another black surface in the same position as the first, and the bar will be again driven in the same direction half round. This action will be again repeated, the differential action of the light on the black and white surfaces keeps the bar moving, and the result will be rotation.

Here is such a pith-bar, blacked on alternate sides, and suspended in an exhausted glass bulb (Fig. 7). I project its image on the screen, and the strong light which shines on it sets it rotating with considerable velocity. Now it is slackening speed, and now it has stopped altogether. The bar is supported on a fibre of silk, which has twisted round till the rotation is stopped by the accumulated torsion. I put a water-screen between the bar and the electric light to cut off some of the active rays, and the silk untwists, turning the bar in the opposite direction. I now remove the water, and the bar revolves rapidly as at first.

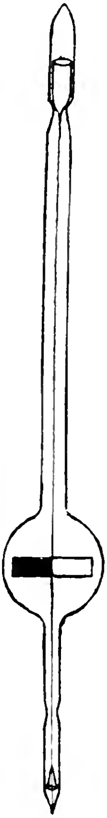

FIG. 7.

From suspending the pith on a silk fibre to balancing it on a point the transition is slight; the interfering action of torsion is thereby removed, and the instrument rotates continuously under the influence of radiation. Many of these little pieces of apparatus, to which I have given the name of radiometers, are on the table, revolving with more or less speed. The diagram (Fig. 8) shows their construction, which is very simple. They are formed of four arms of very fine glass, supported in the centre by a needle-point, and having at the extremities thin disks of pith lampblacked on one side, the black surfaces all facing the same way. The needle stands in a glass cup, and the arms and disks are delicately balanced so as to revolve with the slightest impetus.

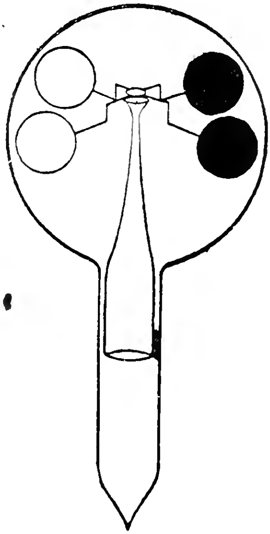

FIG. 8.

Here are some rotating by the light of a candle. This one is now rather an historical instrument, being the first one in which I saw rotation. It goes very slowly in comparison with the others, but it is not bad for the first instrument of the sort that was ever made.

I will now, by means of a vertical lantern, throw on the screen the projection of one of these instruments, so as to show the movement rather better than you could see it on the table. The electric light falling vertically downward on it, and much of the power being cut off by water and alum screens, the rotation is slow. I bring a candle near and the speed increases. I now lift the radiometer up, and place it full in the electric light, projecting its image direct on the screen, and it goes so rapidly that if I had not cut out the four pieces of pith of different shapes you would have been unable to follow the movement.

The speed with which a sensitive radiometer will revolve in the sun is almost incredible; and the electric light, such as I have it in this lantern, cannot be far short of full sunshine. Here is the most sensitive instrument I have yet made, and I project its image on the screen, letting the full blaze of the electric light shine upon it. Nothing is seen but an undefined nebulous ring, which becomes at times almost invisible. The number of revolutions per second cannot be counted, but they must be several hundreds, for one candle has made it spin round forty times a second.

I have called the instrument the radiometer because it will enable me to measure the intensity of radiation falling on it by counting the revolutions in a given time; the law being that the rapidity of revolution is inversely as the square of the distance between the light and the instrument.

When exposed to different numbers of candles at the same distance off, the speed of revolution in a given time is in proportion to the number of candles; two candles giving twice the rapidity of one candle, and three, three times, etc.

The position of the light in the horizontal plane of the instrument is of no consequence, provided the distance is not altered; thus two candles, one foot off, give the same number of revolutions per second, whether they are side by side or opposite to each other. From this it follows that if the radiometer is brought into a uniformly lighted space it will continue to revolve.

It is easy to get rotation in a radiometer without having the surfaces of the disks differently colored. Here is one having the pith-disks blacked on both sides. I project its image on the screen, and there is no movement. I bring a candle near it, and shade the light from one side, when rapid rotation is produced, which is at once altered in direction by moving the shade to the other side.

I have arranged here a radiometer so that it can be made to move by a very faint light, and at the same time its rotation is easily followed by all present. In this bulb is a large six-armed radiometer carrying a mirror in its centre. The mirror is almost horizontal, but not quite so, and therefore, when I throw a beam of electric light vertically downward on to the central mirror, the light is reflected off at a slight angle, and, as the instrument rotates, its movement is shown by the spot of light traveling round the ceiling in a circle. Here again the fog helps us, for it gives us an imponderable beam of light moving round the room like a solid body, and saving you the trouble of looking up at the ceiling. I now set the radiometer moving round by the light of a candle, and I want to show you that colored light does not very much interfere with the movement. I place yellow glass in front, and the movement is scarcely diminished at all. Very deep-colored glass, you see, diminishes it a little more. Blue and green glass make it go a little slower, but still do not diminish the speed one-half. I now place a screen of water in front: the instrument moves with diminished velocity, rotating with about one-fourth its original speed.

| | |
|---|---|
| Taking the action produced by a candle-flame as | 100 |
| Yellow glass reduces it to | 89 |
| Red " " " | 71 |
| Blue " " " | 56 |
| Green " " " | 56 |
| Water " " | 26 |
| Alum " " | 15 |

I now move the candle a little distance off, so as to make the instrument move slower, and bring a flask of boiling water close to it. See what happens. The luminous index no longer moves steadily, but in jerks. Each disk appears to come up to the boiling water with difficulty, and to hurry past it. More and more sluggishly do they move past, until now one has failed to get by, and the luminous beam, after oscillating to and fro a few times, comes to rest. I now gradually bring the candle near. The index shows no movement. Nearer still. There is now a commencement of motion, as if the radiometer were trying to push past the resistance offered by the hot water; but it is not until I have brought the candle to within a few inches of the glass globe that rotation is recommenced. On these pith radiometers the action of dark heat is to repel the black and white surfaces almost equally, and this repulsion is so energetic as to overcome the rotation caused by the candle, and to stop the instrument.

With a radiometer constructed of a good conductor of heat, such as metal, the action of dark heat is different. Here is one made of silvered copper, polished on one side and lampblacked on the other. I have set it moving with a candle slightly the normal way. Here is a glass shade heated so that it feels decidedly warm to the hand. I cover the radiometer with it, and the rotation first stops, and then recommences the reverse way. On removing the hot shade the reverse movement ceases and normal rotation recommences.

If, however, I place a hot glass shade over a pith radiometer, the arms at once revolve the normal way, as if I had exposed the instrument to light. The diametrically opposite behavior of a pith and a metal instrument when exposed to the dark heat radiated from a hot glass shade is very striking. The explanation of the action is not easy, but it depends on the fact that the metal is one of the best conductors of heat, while pith is one of the worst.

One more experiment with this metallic radiometer. I heat it strongly with a spirit-lamp, and the arms spin round rapidly. Now the whole bulb is hot, and I remove the lamp: see what happens. The rotation quickly diminishes. Now it is at rest; and now it is spinning round just as fast the reverse way. I can produce this reverse movement only with difficulty with a pith instrument. The action is due to the metal being a good conductor of heat. As it absorbs heat it moves one way; as it radiates heat it moves the opposite way.

At first I made these instruments of the very lightest material possible, some of them not weighing more than half a grain; and, where extreme sensitiveness is required, lightness is essential. But the force which carries them round is quite strong enough to move a much greater weight. Thus the metallic instrument I have just experimented with weighs over thirteen grains, and here is one still heavier, made of four pieces of looking-glass blacked on the silvered side, which are quickly sent round by the impact of this imponderable agent, and flash the rays of light all round the room when the electric lamp is turned on the instrument.

Before dismissing this instrument let me show one more experiment. I place the looking-glass and the metal radiometer side by side, and, screening the light from them, they come almost to rest. Their temperature is the same as that of the room. What will happen if I suddenly chill them? I pour a few drops of ether on each of the bulbs. Both instruments begin to revolve. But notice the difference. While the movement in the case of the metal radiometer is direct, that of the looking-glass instrument is reverse. And yet to a candle they both rotate the same way, the black being repelled.

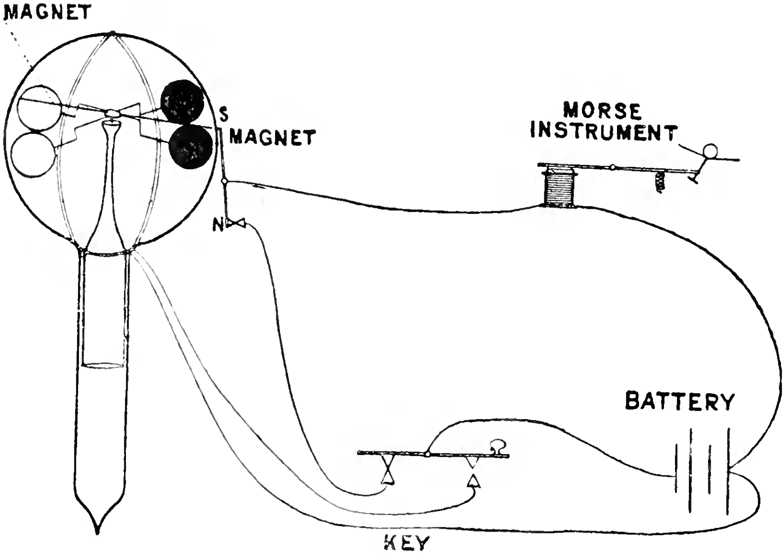

Fig. 9.

Now, having found that this force would carry round a comparatively heavy weight, another useful application suggested itself. If I can carry round heavy mirrors or plates of copper, I can carry round a magnet. Here, then (Fig. 9), is an instrument carrying a magnet, and outside is a smaller magnet, delicately balanced in a vertical position, having the south pole at the top and the north pole at the bottom. As the inside magnet comes round, the outside magnet, being delicately suspended on its centre, bows backward and forward, and, making contact at the bottom, carries an electric current from a battery to a Morse instrument. A ribbon of paper is drawn through the "Morse" by clock-work, and at each contact—at each revolution of the radiometer—a record is printed on the strip of paper by dots; close together if the radiometer revolves quickly, farther apart if it goes slower.

Here the inner magnet is too strong to allow the radiometer to start with a faint light without some initial impetus. Imagine the instrument to be on the top of a mountain, away from everybody, and I wish to start it in the morning. Outside the bulb are a few coils of insulated copper wire, and by depressing the key for an instant I pass an electric current from the battery through them. The interior magnet is immediately deflected from its north-south position, and the impetus thus gained enables the light to keep up the rotation. In a proper meteorological instrument I should have an astatic combination inside the bulb, so that a very faint light would be sufficient to start it, but in this case I am obliged to set it going by an electric current. I have placed a candle near the magnetic radiometer. I now touch the key; the instrument immediately responds; the paper unwinds from the Morse instrument, and on it you will see dots in regular order. I put the candle eight inches off, and the dots come wide apart. I place it five and three-quarters inches off, and two dots come where one did before. I bring the candle four inches from the instrument, and the dots become four times as numerous (Fig. 10), thus recording automatically the intensity of the light falling on the

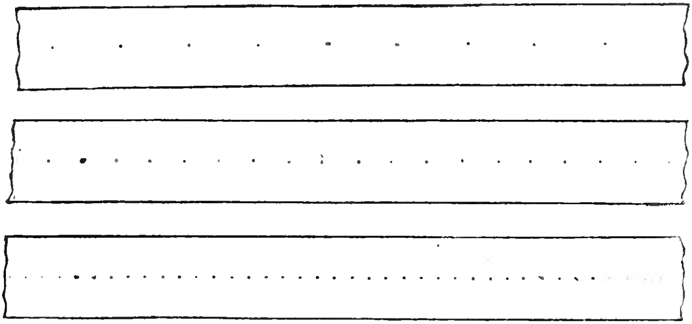

FIG. 10.

instrument, and proving that in this case also the radiometer obeys the law of inverse squares.

This instrument, the principle of which I have illustrated to-night, is not a mere toy or scientific curiosity, but it is capable of giving much useful information in climatology. You are well aware that the temperature, the rainfall, the atmospheric pressure, the direction and force of the wind, are now carefully studied in most countries, in order to elucidate their sanitary condition, their animal and vegetable productions, and their agricultural capabilities. But one most important element, the amount of light received at any given place, has been hitherto but very crudely and approximately estimated, or rather guessed at. Yet it cannot be denied that sunlight has its effect upon life and health, vegetable, animal, and human, and that its relative amount at any place is hence a point of no small moment. The difficulty is now overcome by such an instrument as this. The radiometer may be permanently placed on some tall building, or high mountain, and, by connecting it by telegraphic wires to a central observatory, an exact account can be kept of the proportion of sunlight received in different latitudes, and at various heights above the sea-level. Furthermore, our records of the comparative temperature of different places have been hitherto deficient. The temperature of a country depends partly on the amount of rays which it receives direct from the sun, and partly on the atmospheric and oceanic currents, warm or cold, which sweep over or near it. The thermometer does not discriminate between these influences; but the radiometer will enable us now to distinguish how much of the annual temperature of a place is due to the direct influence of the sun alone, and how much to the other factors above referred to.

I now come to the last question which I stated at the beginning of this lecture, "What is the amount of force exerted by radiation?" Well, I can calculate out the force in a certain way, from data supplied by this torsion apparatus (Fig. 4). Knowing the weight of the beam, the power of the torsion fibre of glass, its time of oscillation, and the size of the surface acted on, it is not difficult to calculate the amount of force required to deflect the beam through a given angle; but I want to get a more direct measure of the force. I throw a ray of light upon one of these instruments, and it gives a push; surely it is possible to measure the amount of this push in parts of a grain. This I have succeeded in doing in the instrument behind me; but before showing the experiment I want to illustrate the principle upon which it depends. Here is a very fine glass fibre suspended from an horizontal bar, and I wish to show you the strength of it. The fibre is only a few thousandths of an inch thick; it is about three feet long, and at the lower end is hanging a scale-pan, weighing 100 grains. So I start with a pull of 100 grains on it. I now add little lead weights, 50 grains each, till it breaks. It bears a pull of 750 grains, but gives way when additional weight is added. You see, then, the great strength of a fibre of glass, so fine as to be invisible to all who are not close to it, to resist a tensile strain.

Now I will illustrate another equally important property of a glass thread, viz., its power to resist torsion. Here is a a still finer glass thread, stretched horizontally between two supports; and in order to show its position I have put little jockeys of paper on it. One end is cemented firmly to a wooden block, and the other end is attached to a little instrument called a counter—a little machine for registering the number of revolutions. I now turn this handle till the fibre breaks, and the counter will tell me how many twists I have given this fibre of glass. You see it breaks at twenty revolutions. This is rather a thicker fibre than usual. I have had them bear more than 200 turns without breaking, and some that I have worked with are so fine that if I hold one of them by the end it curls itself up and floats about the room like a piece of spider's thread.

Having now illustrated these properties of glass fibres, I will try to show a very delicate experiment. I want to ascertain the amount of pressure which radiation exerts on a blackened surface. I will put a ray of light on the pan of a balance, and give you its weight in grains, for I think in this Institution and before this audience I may be allowed a scientific use of the imagination, and may speak of weighing that which is not affected by gravitation.

The principle of the instrument is that of W. Ritchie's torsion balance, described by him in the "Philosophical Transactions" for 1830. The construction is somewhat complicated, but it can be made out on reference to the diagram (Fig. 11). A light beam, *A B*, having two square inches of pith, *C*, at one end, is balanced on a very fine fibre of glass, *D D'*, stretched horizontally in a tube; one end of the fibre being connected with a torsion handle, *E*, passing through the tube, and indicating angular movements on a graduated circle. The beam is cemented to the torsion fibre, and the whole is inclosed in glass, and connected with the mercury pump by a spiral tube, *F*, and exhausted as perfectly as possible. *G* is a spiral spring, to keep the fibre in a uniform state of tension. *H* is a piece of cocoon silk. *I* is a glass stopper, which is ground into the tube as perfectly as possible, and then highly polished and lubricated with melted India-rubber, which is the only substance I know that allows perfect lubrication and will still hold a vacuum. The pith, *C*, represents the scale-pan of the balance. The cross-beam *A B*, which carries it, is cemented firmly to the thin glass fibre, *D*, and in the centre is a piece of mirror, *K*. Now, the cross-beam *A B* and the fibre *D* being rigidly connected together, any twist which I give to the torsion handle *E* will throw the beam out of adjustment. If, on the other hand, I place a weight on the piece of pith *C*, that end of the beam will fall down, and I shall have to turn the handle, *E*, round and round a cer-

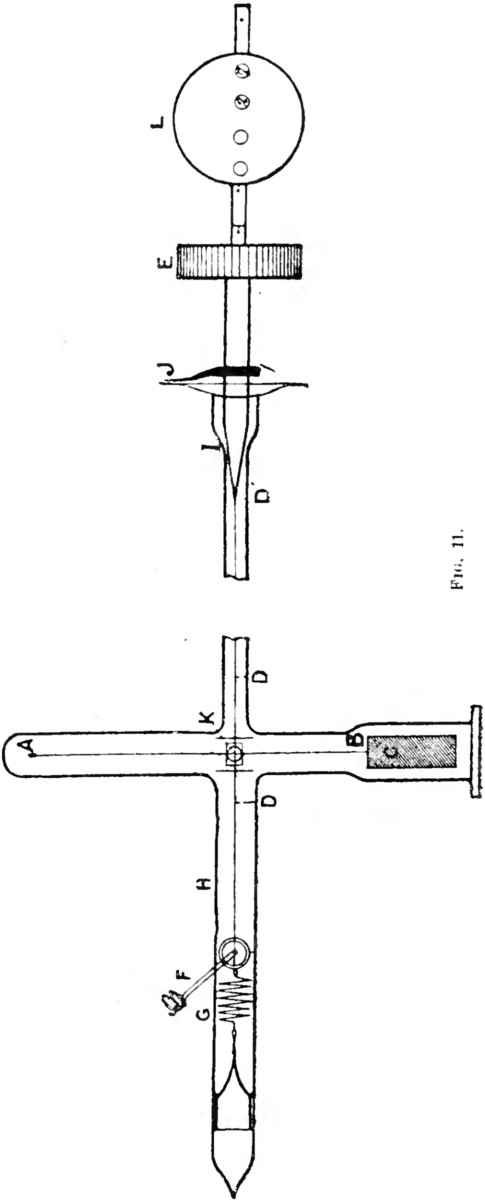

Fig. 11.

tain number of times, until I have put sufficient torsion on the fibre *D* to lift up the beam. Now, according to the law of torsion, the force with which a perfectly elastic body like glass tends to untwist itself is directly proportional to the number of degrees through which it has been twisted; therefore, knowing how many degrees of torsion I must put on the fibre to lift up the $\frac{1}{100}$ of a grain weight, I can tell how many degrees of torsion are required to lift up any other weight; and conversely, putting an unknown weight or pressure on the pith, I can find its equivalent in grains by seeing how much torsion it is equal to. Thus, if $\frac{1}{100}$ of a grain requires 10,000° of torsion, $\frac{1}{50}$ of a grain would require 20,000°; and conversely, a weight which required 5,000° torsion would weigh $\frac{1}{200}$ of a grain. Once knowing the torsion equivalent of $\frac{1}{100}$ of a grain, the ratio of the known to the unknown weights is given by the degrees of torsion.

Having thus explained the working of the torsion balance I will proceed to the actual experiment. On the central mirror I throw a ray from the electric light, and the beam reflected on a particular spot of the ceiling will represent zero. The graduated circle *J* of the instrument also stands at zero, and the counter which I fasten on at the end *L* stands at *O*. The position of the spot of light reflected from the little concave mirror being noted, the torsion balance enables me to estimate the pressure or weight of a beam of light to a surprising degree of exactness. I lift up my little iron weight by means of a magnet (for working in a vacuum I am restricted in the means of manipulating), and drop it in the centre of the pith: it knocks the scale-pan down, as if I had placed a pound weight upon an ordinary balance, and the index-ray of light has flown far from the zero-point on the ceiling. I now put torsion on the fibre to bring the beam again into equilibrium. The index-ray is moving slowly back again. At last it is at zero, and on looking at the circle and counter I see that I have had to make 27 complete revolutions and 301°, or $27 \times 360° + 301° = 10,021°$, before the force of torsion would balance the $\frac{1}{100}$ of a grain.

I now remove the weight from the pith-pan of my balance, and liberate the glass thread from torsion by twisting it back again. Now the spot of light on the ceiling is at zero, and the counter and index are again at *O*.

Having thus obtained the value of the $\frac{1}{100}$ of a grain in torsion degrees, I will get the same for the radiation from a candle. I place a lighted candle exactly 6 inches from the blackened surface, and on removing the screen the pith scale-pan falls down, and the index-ray again flies across the ceiling. I now turn the torsion handle, and in much less time than in the former case the ray is brought back to zero. On looking at the counter I find it registers four revolutions, and the index points to 188°, making altogether $360° \times 4 + 188 = 1628°$, through which the torsion fibre has to be twisted to balance the light of the candle.

It is an easy calculation to convert this into parts of a grain weight; 10,021 torsion degrees representing 0.01 grain, 1628 torsion degrees represent 0.001624 grain.

$$10,021° : 0.01 \text{ grain} :: 1628° : 0.001624 \text{ grain}.$$

The radiation of a candle 6 inches off, therefore, weighs or presses the two square inches of blackened pith with a weight of 0.001624 grain. In my own laboratory, working with this torsion balance, I found that a candle 6 inches off gave a pressure of 0.001772 grain. The difference is only 0.000148 grain, and is fairly within the allowable limits of a lecture experiment. But this balance is capable of weighing to far greater accuracy than that. You have seen that a torsion of 10,021° balanced the hundredth of a grain. If I give the fibre 1° more twist the weight is overbalanced, as shown by the movement of the index-ray on the ceiling. Now 1° of torsion is about the $\frac{1}{10000}$ part of the whole torsion required by the $\frac{1}{100}$ grain. It represents, therefore, the $\frac{1}{10000}$ part of the $\frac{1}{100}$, or the millionth part of a grain.

Divide a grain-weight into a million parts, place one of them on the pan of the balance, and the beam will be instantly depressed!

Weighed in this balance the mechanical force of a candle 12 inches off was found to be 0.000444 grain; of a candle 6 inches off, 0.001772 grain. At half the distance the weight of radiation should be four times, or 0.001776 grain; the difference between theory and experiment being only four-millionths of a grain is a sufficient proof that the indications of this instrument, like those of the apparatus previously described, follow the law of inverse squares. An examination of the differences between the separate observations and the mean shows that my estimate of the sensitiveness of this balance is not excessive, and that in practice it will safely indicate the millionth of a grain.

I have only had one opportunity of getting an observation of the weight of sunlight: it was taken on December 13th, but the sun was so obscured by thin clouds and haze that it was only equal to 10.2 candles 6 inches off. Calculating from this datum, it is seen that the pressure of sunshine is 2.3 tons per square mile.

But, however fair an equivalent ten candles may be for a London sun in December, a midsummer sun in a cloudless sky has a very different value. Authorities differ as to its exact equivalent, but I underestimate it at 1,000 candles 12 inches off.

Let us see what pressure this will give: A candle 12 inches off, acting on 2 square inches of surface, was found equal to 0.000444 grain; the sun, equaling 1,000 candles, therefore gives a pressure of 0.444000 grain; that is equal to about 32 grains per square foot, to 2 cwts. per acre, 57 tons per square mile, or nearly 3,000,000,000 tons on the exposed surface of the globe—sufficient to knock the earth out of its orbit if it came upon it suddenly.

It may be said that a force like this must alter our ordinary ideas of gravitation; but it must be remembered that we only know the force of gravity as between bodies such as they actually exist, and we do not know what this force would be if the temperatures of the gravitating masses were to undergo a change. If the sun is gradually cooling, possibly its attractive force is increasing, but the rate will be so slow that it will probably not be detected by our present means of research.

While showing this experiment I wish to have it distinctly understood that I do not attach the least importance to the actual numerical results. I simply wish to show you the marvelous sensitiveness of the apparatus with which I am accustomed to work. I may, indeed, say that I know these rough estimates to be incorrect. It must be remembered that our earth is not a lampblacked body inclosed in a glass case, nor is its shape such as to give the maximum of surface with the minimum of weight. The solar forces which perpetually pour on it are not simply absorbed and degraded into radiant heat, but are transformed into the various forms of motion we see around us, and into the countless forms of vegetable, animal, and human activity. The earth, it is true, is poised in vacuous space, but it is surrounded by a cushion of air; and, knowing how strongly a little air stops the movement of repulsion, it is easy to conceive that the sun's radiation through this atmospheric layer may not produce any important amount of repulsion. It is true the upper surface of our atmosphere must present a very cold front, and this might suffer repulsion by the sun; but I have said enough to show how utterly in the dark we are as to the cosmical bearings of this action of radiation, and further speculation would be but waste of time.

It may be of interest to compare these experimental results with a calculation made in 1873, before any knowledge of these facts had been made public.

Prof. Clerk Maxwell, in his "Electricity and Magnetism," vol. ii., p. 391, writes as follows: "The mean energy in one cubic foot of sunlight is about 0.0000000882 of a foot-pound, and the mean pressure on a square foot is 0.0000000882 of a pound-weight. A flat body exposed to sunlight would experience this pressure on its illuminated side only, and would therefore be repelled from the side on which the light falls."

Calculated out, this gives the pressure of sunlight equal to about two and a half pounds per square mile. Between the two and a half pounds deduced from calculation and the fifty-seven tons obtained from experiment the difference is great; but not greater than is often the case between theory and experiment.

In conclusion, I beg to call especial attention to one not unimportant lesson which may be gathered from this discovery. It will be at once seen that the whole springs from the investigation of an anomaly. Such a result is by no means singular. Anomalies may be regarded as the finger-posts along the high-road of research, pointing to the by-ways which lead to further discoveries. As scientific men are well aware, our way of accounting for any given phenomenon is not always perfect. Some point is perhaps taken for granted, some peculiar circumstance is overlooked. Or else our explanation agrees with the facts not perfectly, but merely in an approximate manner, leaving a something still to be accounted for. Now, these residual phenomena, these very anomalies, may become the guides to new and important revelations.

In the course of my research anomalies have sprung up in every direction. I have felt like a traveler navigating some mighty river in an unexplored continent. I have seen to the right and the left other channels opening out, all claiming investigation, and promising rich rewards of discovery for the explorer who shall trace them to their source. Time has not allowed me to undertake the whole of a task so vast and so manifold. I have felt compelled to follow out, as far as lay in my power, my original idea, passing over reluctantly the collateral questions springing up on either hand. To these I must now invite the attention of my fellow-workers in science. There is ample room for many inquirers.

Nor must we forget that the more rigidly we scrutinize our received theories, our routine explanations and interpretations of Nature, and the more frankly we admit their shortcomings, the greater will be our ultimate reward. In the practical world fortunes have been realized from the careful examination of what has been ignorantly thrown aside as refuse; no less, in the sphere of science, are reputations to be made by the patient investigation of anomalies.—*Advance Sheets of Quarterly Journal of Science.*

# THE CAUSES OF THE COLD OF THE ICE PERIOD.

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OF COLUMBIA COLLEGE.

A FEW years ago the scientific world was startled by the assertion—made by Charpentier and Agassiz, who had been studying the glacial phenomena of Switzerland—that at no very remote period, geologically speaking, the climate of the northern hemisphere had been very much colder than at present; and that the arctic conditions which now prevail in Greenland—with perpetual snow-sheets, and glaciers reaching the sea—extended as far south as the middle of the present temperate zone.

At first, seriously questioned by most, strenuously denied by some, this theory was found to be sustained by such abundant and indisputable evidence—the inscriptions left by the glaciers themselves—that it was not long before it had secured a general acceptance from geologists. Since then there has been a vast amount of theorizing and investigation, to determine if possible the causes of these remarkable changes of climate.

Up to the present time, however, no theory has been proposed which has been sustained by really satisfying evidence, and there is still much difference of opinion on the question among those who know most about it.

As the subject is one of peculiar geological significance, and great dramatic interest, I venture to bring forward some notes upon it, taken from the geologist's standpoint, hoping that they may contribute in some slight degree to the solution of the problem.

The theories which have been proposed to account for the cold of the Ice period divide themselves into two groups, viz., the cosmical and terrestrial; or those which invoke extraneous or astronomical influences, and those which look to changes in the earth itself, or on its surface, for a sufficient cause or causes.

In the first category may be enumerated the theory of Prof. Croll, that variations in the eccentricity of the earth's orbit have induced great alternations of climate on portions of the earth's surface; that of Belt and Drayson, which supposes the known variability of the angle of the pole with the ecliptic to have been at times sufficiently great to have brought arctic conditions locally down into the temperate zone; also, the speculations that the heat evolved from the sun has been variable in quantity, that the earth has at various times passed through cold spaces in the universe, etc.

In the second category are the views first put forth by Lyell, according to which all the variations of climate recorded in geological history have been induced by changes in the earth itself or on its surface.

In this paper I shall consider only the latter theory, leaving the discussion of the astronomical aspects of the subject to astronomers, mathematicians, and physicists, who alone are competent to thoroughly investigate them.

The explanation given by Lyell of the cold of the Ice period is in conformity with his characteristic conservatism. It is well known that the climatic conditions of all parts of the earth's surface are profoundly affected by their topographical features. This may be seen at a glance by reference to any map on which the isothermal lines are delineated. Continental surfaces are known to be productive of extremes of temperature, while the climate of sea areas is comparatively equable; and the general character of the climate of land and water surfaces is further and locally affected by the configuration and altitude of the land, by the breadth and depth of the oceanic basins, and especially by the ocean-currents. The sea forms the great evaporating surface, and the source from which is derived the enormous quantity of water transported by the system of atmospheric circulation. The local climate of continents is also largely influenced by the winds which blow over them; for these determine, to a considerable degree, the temperature and the annual rainfall; hence the volume and excavating power of rivers, etc. The higher portions of continents, as mountain-chains and plateaux, are colder than the lowlands, and hence become condensers of moisture—places where snow accumulates and glaciers are formed.

A striking illustration of the influence of topography on climate is shown by the high mountains of the tropics, where perpetual snow and glaciers are coexistent with extreme tropical conditions, not only on the same parallel, but within a narrow area. It is evident, then, that topographical changes such as could be easily conceived would readily and perfectly accomplish all the alternations of climate of which we have any evidence in geological history. Recognizing the potency of topographical causes, Lyell sought for, and thought he had found, a sufficient explanation of the contrast between the climates of the Ice period and the present, in changes in the physical geography of the northern hemisphere; assuming and believing that the Glacial period was marked and caused by great elevation and breadth of land-surface about the pole, and, as a corollary and consequence of this proposition, a depression of land and a broadening of oceanic surfaces in the temperate and tropical zones.

This theory affords so simple an explanation of the problem of the Ice period, that it at first strongly commends itself to those who are most cautious and logical in their modes of thought and investigation. Modern science is eminently conservative, and one of the first lessons learned by the investigator of this age is, to exhaust all known causes of phenomena before appealing to the unknown. Still, however plausible this view may be, it must be sustained by solid and substantial proof before it deserves to be regarded as anything but a theory, and before it can be accepted as a rule of faith and practice among geologists. Unfortunately, such proof is not only yet wanting, but there are many facts which, in the light of our present knowledge, seem to indicate that it will never be obtained. The theory of Lyell has, however, been adopted by Prof. Dana, in the last edition of his "Manual," where he says (p. 541), "The occurrence of an Ice period was probably dependent mainly, as suggested by Lyell, on the extension and elevation of the land over the higher latitudes." Prof. Dana has further elaborated and applied the Lyellian hypothesis by suggesting that in the Glacial period barriers of land connected the continents of the two hemispheres, and excluded the tropical currents from the polar seas, in this way cutting off the most powerful equalizing influences, and inducing an exaggeration of the heat of the tropics and the cold of the polar regions. He also claims that high and broad land-surfaces in the circumpolar areas formed great condensers and refrigerators, upon which the moisture, freely and rapidly evaporated from the seething caldron of the circumscribed tropical seas, was precipitated to form almost universal snow-fields and glaciers; certainly very favorable conditions for the production of many of the phenomena which characterized the Glacial period. It must be remembered, however, that this theory presupposes barriers established not only across the North Atlantic and Pacific Oceans, but in the southern hemisphere as well—for this also had its Ice period—barriers connecting the widely-separated promontories of Cape Horn, Cape of Good Hope, and the islands of the East Indian Archipelago; also that, simultaneously with the existence of such barriers, the tropical lands were depressed, and the sea spread its sediments over much of what is in the present age *terra firma*.

In reviewing the theory proposed by Lyell and Dana, I have been impressed with the conviction that if the physical geography of the northern and southern hemispheres had been either alternately or simultaneously such as this theory requires, we should find some evidence of it, apart from the inscriptions made by glaciers nearer the equator than any now exist. In the search for such evidence, however, I have not only failed to find it, but have, as it seems to me, found other things which go far to disprove the theory.

In order to fully state the case, it will be necessary to review several chapters in geological history, and compare the preceding and also the succeeding age with that in which the climate of Greenland came as far south as New York.

The results of such comparisons may be given as follows:

I. It is known to most students of geology that, during the Tertiary age, the climate of all the arctic regions was warm-temperate. A luxuriant forest then covered Greenland, and all the northern portion of this continent; such a forest as could only flourish in a climate as mild as that of our Middle and Southern States.[1]

According to the Lyellian hypothesis this should have been a period of great depression of arctic, and elevation of tropical lands; but we have proof that such was not the case. On the contrary, the land area at the north was broader then than now, while in the tropics it was narrower.

It can be shown, too, that land-connection then existed in northern latitudes between Europe and America, and also between America and Asia. The Atlantic bridge stretched from Greenland to Iceland, thence to the Hebrides and Scotland, which was then part of the

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[1] It has been suggested that the warmth of the Tertiary climate was simply the effect of the residual heat of a globe cooling from incandescence, but many facts disprove this. For example, the fossil plants found in our Lower Cretaceous rocks in Central North America indicate a temperate climate in latitude 35° to 40° in the Cretaceous age. The coal-flora, too, and the beds of coal, indicate a moist, equable, and warm but not hot climate in the Carboniferous age, millions of years before the Tertiary, and 3,000 miles farther south than localities where magnolias, tulip-trees, and deciduous cypresses, grew in the latter age. Some learned and cautious geologists even assert that there have been several Ice periods, one as far back as the Devonian.

European Continent. The Pacific bridge was where Behring's Straits now are.

These conclusions are deducible from the following facts:

1. Our American flora, which began in the Cretaceous, spread in the Tertiary age to Europe on the one hand, and to China and Japan on the other; and this could only have taken place when the continents were connected. The characteristic plants of this flora have been found fossilized on the Upper Missouri, on Mackenzie's River, Disco Island, Greenland, Iceland, the island of Mull, and on the continent of Europe as far south as Italy. No collection has been made of Tertiary plants in Japan and China, but the living flora of these countries contains a large number of species identical with those found, either living or fossil, in North America. The remarkable similarity between the flora of Northeastern Asia and that of America, so clearly shown by Prof. Gray, is such as to demonstrate a community of origin, and that its place of origin was America may be fairly inferred from the character of the present American flora and from the facts that a large part of the most characteristic genera are found here in the Cretaceous rocks, and many of the living *species* in our fresh-water Tertiaries.

2. Marine Tertiary deposits are almost completely absent from the arctic lands, while they now skirt or cover most tropical continents and islands.

Rocks containing marine Tertiary fossils are conclusive evidence of the submergence in Tertiary times of the land in the localities where they occur; and they would not fail to exist over great areas in the arctic, had the land there been more depressed in the Tertiary age than now; since most of the country which borders the Arctic Sea, both in America and Asia, lies but little above the sea-level.

The Tertiary strata, that have yielded more than three hundred species of land-plants at the far north are generally fresh-water and marsh deposits, containing fresh-water shells and beds of lignite similar to those of the central portions of our own continent. In contrast to the state of things thus indicated, the marine Tertiaries, which form the margins of our South Atlantic and Gulf States, the West Indies, the Isthmus, and the northern part of South America, are automatic records of high sea or low land level, in the tropical regions during Tertiary times.

These facts seem to prove that in the period when a warm-temperate climate prevailed over all the arctic regions, the land was broader and higher than now at the north, lower and narrower at the south; and that barriers did then exist which excluded the tropical ocean-currents from the arctic sea.

II. Just what the topography of the arctic regions was during the Glacial period, we have as yet no very full and accurate information. It has been generally supposed that at least certain areas in the north were then high, but this cannot be said to be proved. That the arctic lands have been at *some time* raised higher than now, is shown by the fiords of the northern coasts, which, as first pointed out by Dana, must have been excavated by subaërial erosion; but a large part of that erosion may have been effected in the Tertiary age, and perhaps it was chiefly accomplished then.

When a dense forest clothed the arctic lands, and spread over continuous land-surfaces to Europe and Asia, these now half-submerged fiords were valleys traversed by flowing streams; for the abundant Tertiary vegetation of the far north proves the country to have been well watered. That these fiords were filled with glaciers during the Ice period is certain, as the bottoms and sides of many of them are glaciated, but this would happen again with a depression of temperature, and without a depression of sea-level. The fact that the glaciated surface of the bottoms of fiords in Sweden and America passes under the sea, and reaches as far as observation can be carried, is not the proof of elevation it has been claimed to be, for the glaciers that now reach the sea must score their beds to the depth of several hundred feet, before their extremities are lifted up by the one-tenth greater gravity of water, and are floated off as icebergs.[1]

Prof. J. W. Dawson holds the view that the Glacial period was one of depression at the north, as he finds marine shells in the *bowlder clay* of the St. Lawrence Valley; and he attributes much of the glaciation of Eastern North America to icebergs dragged over the submerged land.

Croll says ("Climate and Time," p. 391):

> "The greater elevation of the land (in the Ice period) is simply assumed as an hypothesis to account for the cold. The facts of geology, however, are fast establishing the opposite conclusion, viz., that when the country was covered with ice, the land stood in relation to the sea at a lower level than at present, and that the continental periods or times, when the land stood in relation to the sea at a higher level than now, were the warm inter-glacial periods, when the country was free of snow and ice, and a mild and equable condition of climate prevailed. This is the conclusion toward which we are being led by the more recent revelations of surface-geology, and also by certain facts connected with the geographical distribution of plants and animals during the Glacial epoch."

According to the investigations of Bohtlingk and Kjerulf, Scandinavia was 600 feet lower during the Glacial period than now. Erdmann, on the contrary, supposes that Sweden was higher during the Glacial epoch than at the present day, from the fact that polished

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[1] Some of the huge tabular icebergs, which have been observed off the Antarctic Continent, projected more than 500 feet above the surface of the ocean; and as for every foot above water there must have been 8.7 feet submerged, the whole thickness of the ice-sheet, from which these bergs were detached, must have been over 5,000 feet, and such a glacier must grind the sea-bottom to a depth of over 4,000 feet. (*See* Croll, "Climate and Time," p. 385.)

rock-surfaces extend beneath the sea; but this, as we have seen, proves no such thing.

Dana bases his statement that the northern portion of our continent was highest in the Ice period on the system of deep, now-buried channels, by which its surface was once furrowed, and upon the fiords which fringe the northern coast; but, as elsewhere stated, we have no proof that all, or nearly all, this erosion was not effected previous to the Glacial epoch. Reviewing all the facts that have been cited, we can at least say that the indications of elevation are not nearly so well marked in the Quaternary as in the Tertiary; and the evidence of such elevation as would shut out the tropical currents from the Arctic Sea in the Quaternary age is wholly wanting.

In the Champlain epoch the northern land was greatly depressed, as we learn from the fact that the clays containing marine shells are found on the present land at a constantly-increasing elevation as we go toward the north. About New York the Champlain clays reach from 50 to 100 feet above the ocean-level; on Lake Champlain they are 400 feet, at Montreal nearly 500 feet, at Labrador 800, in Barrow's Straits 1,000, and at the extreme point reached by the Polaris Expedition, on the coast of Greenland, 1,800 feet above the sea (Bessel).

On the European coast of the Atlantic we have proof of an elevation of the land during the Tertiary, and a subsidence in the Quaternary, similar to those described above. Hence we may infer that in the Champlain epoch the topography of the arctic regions was just that which would be favorable for the transfer by ocean-currents of the heat of the tropics to the arctic, and a prevalence over the arctic regions of a warm climate. But it must be said that all the shells found in the Champlain clays, from Lake Champlain to Greenland, are of a decided boreal character, which indicates that during the entire deposition of that formation a climate scarcely warmer than that of Greenland prevailed from New England northward.

If it is true that the Glacial epoch was one of elevation at the north—an elevation of the land much greater than the present—the change to the depressed condition of the Champlain epoch, when the sea stood from 1,500 to 1,800 feet higher on the coast of Greenland than it now does, must have been comparatively sudden; and if, as has been asserted, the depression of the Champlain epoch was common to the whole northern hemisphere, it could have been effected only by a great change in the figure of the earth, or by a flow of the ocean-waters into the polar regions, such as has been suggested by Adhemar and Croll. These writers hold the view that the effect of the extreme cold of the Glacial period was to form an ice-cap some miles in thickness over the arctic regions, and that this ice-cap moved the centre of gravity of the earth toward the pole, so that the oceanic waters flowed into this hemisphere and thus elevated the sea-level.

One result of the formation of an ice-cap over the polar regions alternately in one and the other hemisphere might very well be, as claimed by Croll and admitted by Sir William Thomson, such great ebbs and flows of the ocean-waters as we find recorded in the Champlain clays, and the present depressed sea-level; but some more conclusive evidence of an ice-cap will be asked by cautious reasoners than these alternations of level: such evidence, for example, as universal glaciation over all of North America of 40° north latitude. No such evidence has as yet been adduced; but, on the contrary, observers report an absence of ice-marks in the interior of the continent northwest of the Great Lakes. This we might take to be proof that the glaciers of the Ice period were limited to the highlands comparatively near the ocean, the source of evaporation, and that the interior was so dry then and now that no glaciers could be formed there. This is, however, a subject which requires further investigation. Whatever be its cause, the uniformity and magnitude of the change of sea-level from the Tertiary emergence to the Champlain submergence, and then to the present, render it one of the most remarkable phenomena recorded in geological history, and one that with careful study will probably throw much light upon the great dynamical influences that have produced changes on the earth's surface.

III. Either simultaneously or alternately with the extremes of warmth and cold, which we find recorded in the northern, warm and cold periods prevailed in the southern hemisphere. The evidences of a Glacial period in South America are as conclusive as on our own continent; but it is difficult to conceive how barriers could, at that time, have been thrown across the great open oceans—the South Atlantic and South Pacific—in such a way as to confine the tropical currents to the central portions of these oceans.

We are, perhaps, not justified in saying that such barriers never did exist, but it will be conceded that the difficulties which oppose their erection there are much greater than in the northern hemisphere; and the hypothesis which supposes their existence in the Glacial period of the southern hemisphere is so entirely unsupported by facts, that we are compelled to regard it as mere conjecture.

In any discussion of the phenomena and causes of the Ice period we are, up to the present time, somewhat limited and embarrassed for want of a wider range of observation. The facts are not yet all in. Nearly all the detailed and careful observations made on the glacial phenomena of the northern hemisphere have been limited to the eastern half of North America and the western part of the European Continent. Here the traces left by the glaciers are really stupendous in their magnitude and extent; and we have demonstrative evidence that, during the Ice period, the glaciers and snow-fields of Greenland stretched continuously down along the Atlantic coast of North America to and below New York, and that the highlands of New England

and Eastern Canada were completely covered, and probably deeply buried, in sheets of ice and snow. In the British Islands and Norway the inscriptions made by ancient glaciers are scarcely less broad and profound, and it is even conjectured that the bed of the shallow North Sea is itself glaciated throughout. These evidences of vast accumulations of ice and snow on the borders of the Atlantic have led some theorists to suppose that the Ice period was attended, if not in part caused, by a far more abundant evaporation from the surface of the Atlantic than takes place at present; and it has even been conjectured that submarine volcanoes in the tropics might have loaded the atmosphere with an unusual amount of moisture. This speculation seems to me, however, both improbable and superfluous; improbable, because no traces of any such cataclysm have been discovered, and it is more than doubtful whether the generation of steam in the tropics, however large the quantity, would produce glaciation of the polar regions. The ascent of steam and heated air loaded with vapor to the altitude of refrigeration, would, as it seems to me, result in the rapid radiation of the heat into space, and the local precipitation of unusual quantities of rain; and the effect of such a catastrophe would be slowly propagated and feebly felt in the arctic and antarctic regions. The hypothesis is superfluous, because all we want, to restore the conditions recorded in the glaciated area, is simply a depression of temperature; by this the climate of Greenland, with all the attending phenomena, would be brought down on both sides of the Atlantic to the lowest point where the average annual temperature of Greenland prevailed.

This is, I think, proved by the condition of Greenland itself; remote as it is from evaporating surfaces of warm water, the precipitation of moisture upon that continent is, however, sufficient to cover it deeply under sheets of snow and ice; the whole interior being occupied by a continental glacier; and it is easy to see that, with a depression of the average annual temperature 10°, the highlands of Labrador would be brought into the same condition. With a still further depression the elevated portions of New England, the Adirondacks, and the highlands north of the lakes, would be completely encased in snow and ice. If the flow of the St. Lawrence were arrested, and the annual precipitation of the region drained by it were congealed, and retained from year to year, glaciers would soon form, and creep down from the highlands into the valleys, until the basins of the great lakes and the troughs of the Hudson and St. Lawrence would be completely filled with ice. On the eastern side of the Atlantic this state of things would be still more rapidly reached, inasmuch as, from the effect of the Gulf Stream, the coast climate is considerably more moist.

So far, then, as the region bordering the North Atlantic is concerned, a simple depression of temperature from any cause whatever, terrestrial or cosmical, would produce all the phenomena of the Ice period.

Before we can certainly determine, however, what the nature of the cause producing the cold of the Ice period was, we must know more accurately where and how the cause operated. To accomplish this, observations must be made over all those portions of the northern and southern hemispheres where the traces of former glaciers are visible.

In a general way we know that there was a cold period throughout the northern hemisphere, as glacial phenomena are reported from Siberia and Northwestern America, somewhat similar to those which we find on the Atlantic coast. In regard to Siberia very much remains to be learned. Nearly the whole of the northern portion of this great area is flat, and is deeply covered with Quaternary deposits; and it has been conjectured that in the Ice period the shallow sea off the Siberian coast was solidly frozen throughout a great portion of its breadth, and thus formed an ice-dam, behind which the drainage of the northern slope accumulated alternately as sheets of ice and bodies of fresh water.

The northern portion of the interior of our own continent is said to be without distinct marks of glacial action. Should this statement be confirmed by further observation, it would not, however, be a formidable argument against a general Glacial period; for intense cold would leave no permanent record there, unless there was sufficient precipitation of moisture to form glaciers. As this region is now very dry and sterile, it was perhaps so through the Ice period, and snow at no time fell there in sufficient quantity to form glaciers. On the mountains of British America and Alaska, of Oregon and California, there are abundant evidences of glaciers far more numerous and extensive than any now existing; and these furnish demonstrative evidence that this region shared in the effects of a distinct Ice period. The slopes of the Cascade Mountains in Oregon are everywhere glaciated, and perhaps no more impressive record of the Ice period exists than that formed by the planed and furrowed surfaces, the *roches moutonnées*, etc., by which all the higher portions of the belt, twenty to thirty miles in width, are marked. No ice-sheet moved in that region from the north, as there was no district of northern highlands where continental glaciers could be generated; but the glaciers radiated east and west from various centres along the crests of the chain, and descended at least 2,500 feet below the present snow line. This I determined by actual barometric observation in many places, and I nowhere found the lower limit of glacial action, as the planed and furrowed surfaces passed beneath the alluvium of the lower valleys.

Whether there was a depression of the Western coast during the Champlain epoch, corresponding to that recorded along the shores of the Atlantic, we are as yet unable to say, as careful observations on this interesting subject are wanting; and these are not easily made on this iron-bound and earthquake-shaken coast, where there has been so little low and level land upon which Champlain clays could be deposited.

That this portion of the continent—like the Eastern side—has been higher than now, we learn from the deeply-excavated channels of the Golden Gate, the straits of Carquines, the mouth of the Columbia, the Canal De Haro, etc. But this erosion was produced in part if not altogether in Tertiary times. At Shoalwater Bay and about Steilacoom, there are raised beaches, apparently of ancient date, but farther south the changes of level have been so frequent and local that nothing like system has been educed from a comparison of the old shore-lines.

Taken as a whole, the glacial inscriptions of the West coast, as studied by King and Le Conte in California, and myself in Oregon, prove an Ice period as distinctly as do the glacial marks of the Atlantic coast and the Mississippi Valley; but the peculiar topography of the Western country has made the record a somewhat different one.

From the foregoing facts it seems to me that we are justified in concluding:

1. That however simple and plausible the Lyellian hypothesis may be, or however ingenious the extension or application of it suggested by Dana, it is not sustained by any proof, and the testimony of the rocks seems to be decidedly against it.

2. Though much may yet be learned from a more extended and careful study of the glacial phenomena of all parts of both hemispheres, the facts already gathered seem to be incompatible with any theory yet advanced which makes the Ice period simply a series of telluric phenomena, and so far strengthens the arguments of those who look to extraneous and cosmical causes for the origin of these phenomena.

# A FITTING RECOGNITION OF AMERICAN SCIENCE.

PRESENTATION OF THE RUMFORD MEDAL BY THE AMERICAN ACADEMY OF SCIENCE TO DR. DRAPER.—FROM THE PROCEEDINGS OF THE ACADEMY.

AT the six hundred and eighty-ninth meeting of this body, held March 8, 1876, the chairman of the Rumford Committee introduced the *special* business of the evening, and handed to the President, Hon. Charles Francis Adams, the Rumford medals (in gold and silver), on each of which had been engraved the following inscription: "Awarded by the American Academy of Arts and Sciences to John W. Draper, for his researches in radiant energy, May 25, 1875."

In presenting the medals the President said:

Gentlemen of the Academy: The foundation of this Society, you all know, dates back but four years less than a century. It followed close upon the adoption of the form of government of the State itself. Further than this privilege of a corporation, I am not aware that the State has since bestowed any aid on it whatever. During the long period that has intervened, the individual members have steadily and honestly contributed their labors and their money to the advancement of science and of the arts, the evidence of which is to be found as well in the collections of the library as in the long series of their published transactions. We have not been so lucky as to earn the favor of the generous and wealthy at all in the proportion given to some other institutions of the same general character. In point of fact, we have to ascribe our success more to our own energies than to the assistance of patrons. This is no bad sign for the future. The Academy was never in more healthy and vigorous condition than at this moment. The meetings are constantly attended by members who appear to give or to receive with interest the many valuable contributions to knowledge which ultimately take their place in the formidable volumes open to the inspection of the world.

Yet it is not to be understood from what I have said that the institution has been altogether without liberal assistance from several sources. The most remarkable instance of a benefaction was perhaps the earliest, that of Benjamin Thompson, better known under the name of Count Rumford, who, eighty years ago, presented to the Academy the sum of five thousand dollars, to be devoted to the stimulation of the study of the various phenomena connected with light and heat, by the presentation of medals of value as honorary rewards to successful research. It is to the credit of the Academy, in these degenerate days, to find that its administration of this property has fully justified the confidence of the donor, the original sum having increased more than fourfold over and above the cost of the medals which have from time to time been awarded to successful investigation of the great subjects proposed for study and examination.

It now becomes my agreeable duty to announce the fact that, after a careful review of the meritorious service of Prof. Draper in this great field of inquiry, the committee having the subject in their charge have, for reasons given by them, recommended through their chairman, that the medals prescribed in the deed of trust should be presented to him as having fully deserved them. It falls to my lot only to recapitulate in brief some of these reasons.

In 1840 Dr. Draper independently discovered the peculiar phenomena commonly known as Moser's images, which are formed when a medal or coin is placed upon a polished surface of glass or metal. These images remain, as it were, latent, until a vapor is allowed to condense upon the surface, when the image is developed and becomes visible.

At a later period he devised the method of measuring the intensity of the chemical action of light, afterward perfected and employed by Bunsen and Roscoe in their elaborate investigations. This method consists in exposing to the source of light a mixture of equal volumes of chlorine and hydrogen gases. Combination takes place more or less rapidly, and the intensity of the chemical action of the light is measured by the diminution in volume. No other known method compares with this in accuracy, and most valuable results have been obtained by its use.

In an elaborate investigation, published in 1847, Dr. Draper established experimentally the following important facts:

1. All solid substances, and probably liquids, become incandescent at the same temperature.

2. The thermometric point at which substances become red-hot is about 977° Fahr.

3. The spectrum of an incandescent solid is continuous; it contains neither bright nor dark fixed lines.

4. From common temperatures nearly up to 977° Fahr., the rays emitted by a solid are invisible. At that temperature they are red, and, the heat of the incandescing body being made continuously to increase, other rays are added, increasing in refrangibility as the temperature rises.

5. While the addition of rays so much the more refrangible as the temperature is higher is taking place, there is an increase in the intensity of those already existing. Thirteen years afterward Kirchhoff published his celebrated memoir on the relations between the coefficients of emission and absorption of bodies for light and heat, in which he established mathematically the same facts, and announced them as new.

6. Dr. Draper claims, and we believe with justice, to have been the first to apply the daguerreotype process to taking portraits.

7. Dr. Draper applied ruled glasses and specula to produce spectra for the study of the chemical action of light. The employment of ruled metallic specula for this purpose enabled him to avoid the absorbent action of glass and other transparent media, as well as to establish the points of maximum and minimum intensity with reference to portions of the spectrum defined by their wave-lengths. He obtained also the advantage of employing a normal spectrum in place of one which is abnormally condensed at one end and expanded at the other.

8. We owe to him valuable and original researches on the nature of the rays absorbed in the growth of plants in sunlight. These researches prove that the maximum action is produced by the yellow rays, and they have been fully confirmed by more recent investigations.

9. We owe to him, further, an elaborate discussion of the chemical

action of light, supported in a great measure by his own experiments, and proving conclusively, and, as we believe, for the first time, that rays of all wave-lengths are capable of producing chemical changes, and that too little account has hitherto been taken of the nature of the substance in which the decomposition is produced.

10. Finally, Dr. Draper has recently published researches on the distribution of heat in the spectrum, which are of the highest interest, and which have largely contributed to the advancement of our knowledge of the subject of radiant energy.

And now, in the absence of Dr. Draper, unable at this inclement season to execute a fatiguing journey, it gives me pleasure to recognize you, Mr. Quincy, as his worthy and competent representative.

I pray you, in receiving these two medals on his behalf, in accordance with the terms of the original trust, to assure him, on the part of the Academy, of the high satisfaction taken by all its Fellows in doing honor to those who, like him, take a prominent rank in the advance of science throughout the world.

Mr. Quincy, on receiving the medals, said:

Mr. President: In the name and on the behalf of Dr. Draper I have the honor to receive the Rumford medals in gold and silver, which the Academy has been pleased to award to him, and I will have them safely conveyed to him to-morrow, together with the assurances of the satisfaction of the Academy in this action which you wish me to communicate to him. In common with yourself, sir, and all the Fellows present, I regret that that eminent person is unable to attend this meeting and receive the medals himself. And, personally, I regret the absence of Dr. Wolcott Gibbs, who had promised to perform this grateful service for his friend, and who would have been able to make a more suitable reply to the able discourse with which you have accompanied the presentation of the medals, and to have done more justice to the claims of Dr. Draper to this distinction than I can pretend to do. Dr. Gibbs having also been unavoidably prevented from being present this evening, I have now the honor to read a communication from Dr. Draper to the Academy, in acknowledgment of this testimony to his services to science.

Mr. Quincy then read the following letter:

To the American Academy of Arts and Sciences: Your favorable appreciation of my researches on radiations, expressed to-day by the award of the Rumford medals, the highest testimonial of approbation that American science has to bestow on those who have devoted themselves to the enlargement of knowledge, is to me a most acceptable return for the attention I have given to that subject through a period of more than forty years, and I deeply regret that through ill-health I am unable to receive it in person.

Sir David Brewster, to whom science is under so many obligations for the discoveries he made, once said to me that the solar-spectrum is a world in itself, and that the study of it will never be completed. His remark is perfectly just.

But the spectrum is only a single manifestation of that infinite ether which makes known to us the presence of the universe, and in which whatever exists—if I may be permitted to say so—lives and moves and has its being.

What object, then, can be offered to us more worthy of contemplation than the attributes of this intermedium between ourselves and the outer world?

Its existence, the modes of motion through it, its transverse vibrations, their creation of the ideas of light and colors in the mind, the interferences of its waves, polarization, the conception of radiations and their physical and chemical effects—these have occupied the thoughts of men of the highest order. The observational powers of science have been greatly extended through the consequent invention of those grand instruments, the telescope, the microscope, the spectrometer. Through these we have obtained more majestic views of the nature of the universe. Through these we are able to contemplate the structure and genesis of other systems of worlds, and are gathering information as to the chemical constitution and history of the stars.

In this noble advancement of science you, through some of your members, have taken no inconspicuous part. It adds impressively to the honor you have this day conferred on me, that your action is the deliberate determination of competent, severe, impartial judges. I cannot adequately express my feelings of gratitude in such a presence, publicly pronouncing its approval on what I have done.

I am, gentlemen, very truly yours, JOHN W. DRAPER.

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# BLASIUS'S THEORY OF STORMS.[1]

By Prof. VICTOR L. CONRAD, M. A.

I PROPOSE to give some account of a new theory of storms put forth by Prof. Blasius, of Philadelphia, formerly Professor of Natural Sciences in the Lyceum of Hanover, Germany. His attention was first drawn to the subject of storms in the year 1851. Having witnessed the destructive effects of a tornado at West Cambridge, Massachusetts, he made a careful survey of its entire track. The facts discovered about the middle of its course, where the most damage had been caused, favored the rotary theory of Redfield; those near the end of its path seemed to confirm the inblowing theory of Espy; but those at the beginning could not be explained by either theory. Discouraged and perplexed by these conflicting results, he resolved to apply to storms the analogy drawn from the life of an animal in its origin or embryo, its development to maturity, and its end. From this he argued that storms must have a beginning, a duration, and an end, with phases peculiar to each stage of their development and progress, like an animal; and, guided by this analogy, he made a careful reëxamination and application of all the facts he had

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[1] "Storms: Their Nature, Classification, and Laws, with the Means of predicting them by their Embodiments the Clouds." By William Blasius. Philadelphia: Porter & Coates.

discovered, and came to the following conclusion respecting the origin and distinct character of tornadoes and storms :

> ORIGIN OF STORMS AND TORNADOES.—"I had found the existence of two opposing currents of air of different temperature, coming respectively from northwest and southwest, acting suddenly against each other after a sultry calm of some duration; and shortly, a third gyratory force making its appearance between them, traveling in their diagonal, growing to such magnitude as to obliterate all trace of the straight-line forces of the opposing currents, and finally abruptly disappearing. The two currents must have been, during the period of sultry calm, in a state of equilibrium, since the clouds were observed to remain for some time almost stationary. South of the tornado's track the southwest wind prevailed until the beginning of the tornado, and, from information obtained for me by ex-President Hill, it appeared that a storm had traveled from northwest to southeast over the States of New Hampshire and Vermont, and that during its progress a southwest wind was replaced by a northwest wind. I was thus led to conclude that the storm announced that afternoon by the black bank of cloud consisted in the conflict of two aërial currents of different temperature—that the colder northern current displaced the warmer southern current in the direction from northwest to southeast, gradually decreasing in velocity until, north of Waltham, West Cambridge, and Medford, it came to a perfect standstill, producing the sultry calm felt before the tornado.
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> "Here the two currents, being in equilibrio, exerted a great compressive force against each other. The equilibrium was disturbed by the uneven configuration of the earth around Prospect Hill. This disturbance produced the tornado, which traveled, not in the direction of the storm toward the southeast, but in the diagonal of the two opposing currents over their region of calm at their line or meeting, and in and underneath the black bank of clouds stretched out from west to east which must have marked this line of meeting.
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> "I came thus to two distinct phenomena—the tornado, and the storm in the ordinary sense of the word—both different in their origin, nature, direction, progress, and appearance, and governed by entirely different laws."

Continuing his observations for several years, he came to the conclusion—

> "That storms in the temperate zone at least, and over the United States, are the *effect* of the conflict of opposing aërial currents of different temperatures, and not the *cause* of these currents and temperatures, as seems to be assumed by some cyclonists."

Continuing and extending his observations and studies in the general field of meteorology, our author compares his own method of procedure with that usually pursued by others, as follows :

> "Having found, during my investigations, that tornadoes and other storms are different phenomena, and that they follow different laws, I endeavored to investigate storms in general by the same method I had used with the tornado.
>
> "My researches were not made by filling out the ordinary meteorological formulæ from observations made three or four times daily, as is the custom. I had learned that no storm will be accommodating enough to develop itself just at the specified periods for observing; I do not believe that this method will ever lead to any definite results.

> "A storm must be treated as an individual which is subject to development. This is difficult, on account of the nature of the subject, but it is possible and essential. We must take the storm at its earliest appearance, and not lose sight of it for one moment until we know it throughout its whole extent, in all its parts, from beginning to end."

This view of Prof. Blasius coincides with that of Sir William Herschel, who says:

> "In endeavoring to interpret the weather, we are in the position of a man who hears at intervals a few fragments of a long history related in a prosy, unmethodical manner. A host of circumstances omitted or forgotten, and the want of connection between the parts, prevent the hearer from obtaining possession of the entire story."

DEFINITION OF A STORM.—But leaving methods and passing to results, our author defines a storm in general to be "*the movement of the air caused by its tendency to reëstablish an equilibrium which has been disturbed;* and we may call all such movements storms, whether they are gentle breezes or furious hurricanes, whether accompanied by more or less condensation of moisture or clouds, or even by none at all," as in deserts.

CLASSIFICATION OF STORMS.—As the result of his investigations in aërial movements in the northern hemisphere, Prof. Blasius presents the following classification of all storms:

1. LOCAL OR VERTICAL STORMS. Stationary. Centripetal.—Produced by a tendency of the atmosphere to reëstablish in a vertical direction an equilibrium that has been disturbed. Characteristic cloud—*cumulus*.

2. PROGRESSIVE OR LATERAL STORMS. Traveling.—Produced by a tendency of the atmosphere to reëstablish in a lateral direction an equilibrium that has been disturbed. They are of two kinds:

(*a*.) EQUATORIAL OR NORTHEAST STORMS. Winter storms.—Produced by a warm current displacing a cool one to supply a deficiency toward the poles. Temperature changing from cool to warm.—Direction to the northeastern quadrant. Characteristic cloud—*stratus*.

(*b*.) POLAR OR SOUTHEAST AND SOUTHWEST STORMS. Summer storms.—Produced by a cool current displacing a warm one to supply a deficiency toward the equator. Temperature changing from warm to cool. Direction to the southern semicircle. Characteristic cloud—*cumulo-stratus*.

3. LOCO-PROGRESSIVE OR DIAGONAL STORMS. Traveling locally. Rotary—tornadoes, hailstorms, sandstorms, water-spouts, etc.—Produced by a tendency of the atmosphere to reëstablish the equilibrium of a *polar storm* which has been disturbed in the plane of meeting by a peculiar configuration of the ground.—Direction, the diagonal of the forces of the two opposing currents transversely through the polar storm.—Characteristic cloud—*conus*.

In order that the significance of the above classification may be clearly understood, it will be well to notice in brief outline the general movements of the atmosphere surrounding the globe, more especially those in the northern hemisphere.

Atmospheric Currents.—All storms owe their origin to the heat of the sun, which produces differences of temperature in different portions of the earth, and thereby causes all the movements and currents which take place in the atmosphere around the globe. As the air at the equator is more highly heated by the sun than that of any other region, it expands, becomes lighter and rises, causing a partial vacuum or deficiency there at the surface of the earth. The air north and south of it at once moves forward from opposite directions to supply this deficiency at the equator, and this in turn becomes heated and ascends. Other air again moves forward from north and south to replace it, and thus an upward current at the equator, and a north and south polar current at the surface toward the equator, are established. These north and south polar currents cause a deficiency of air at the poles, and the heated air which has risen at the equator into the upper region of the atmosphere divides and moves forward toward the opposite poles to supply the deficiency caused there. Thus, upper currents in opposite directions from the equator to the poles are also established in order to restore the equilibrium disturbed by the surface polar currents flowing toward the equator.

But by the time the air of the upper currents has reached the region of the tropics, it has become cooler and heavier, and descends to the surface of the earth. Here it divides into two currents—one flowing back to the equator, forming the trade-winds; and the other, becoming warmer again at the surface, flows toward the poles, meeting the polar current somewhere north of the tropic in the northern hemisphere, and south of it in the southern. *This meeting of the equatorial or tropical and polar currents in the temperate zone, and the various phenomena attending and resulting from it, are the most significant and important facts which constitute the basis of Prof. Blasius's theory of storms,* in distinction from the centripetal theory of Espy, and the rotary theory of Colonel Clapper, as developed by Piddington, Thom, Dove, and others, and better known in this country as the cyclone theory of Redfield.

The following diagram (Fig. 1) will serve to indicate the movements and courses of the general atmospheric currents of the earth, as above described, the arrows showing the directions in which they move.

The two currents above referred to—the polar and the equatorial or tropical—are of different temperatures, and move horizontally in opposite directions toward each other. When they meet they overlap each other somewhat like two wedges with their sharp ends forward. The warmer current, being lighter, glides obliquely over the cooler current, and moves northward; and the cooler current, being heavier, moves beneath it on the surface of the earth southward, just as two currents, warm and cold, flow over each other in opposite directions through an open window or door of a heated room.

The plane of meeting between these two currents is more or less inclined northward in the northern hemisphere, for the reason just stated; and the lower end of the plane, or the space of air between these two currents where they meet on the surface of the earth,[1] constitutes the centre line or area proper of the storm, and the region of lowest barometer. The horizontal plane beneath this inclined plane[2] is the geographical extent of the region affected by the storm and the region of low barometer. The place where the currents meet is constantly changing with the changing seasons, following the sun northward in summer and southward in winter. These changes of locality do not, however, take place in one continuous movement of the atmosphere; but with successive oscillations, like the waves of a rising tide, each succeeding wave advancing farther and receding less than the one before it, until its most northern or southern limit is reached—as represented by the numbers 1 and 2 in the diagram—when the oscillations in the opposite direction again begin. Whenever the lower end of the plane of meeting between the two opposing currents at *B* oscillates or passes over any place on the surface of the earth, it will cause storm or change of weather there—a change of wind, of temperature, and of atmospheric pressure.

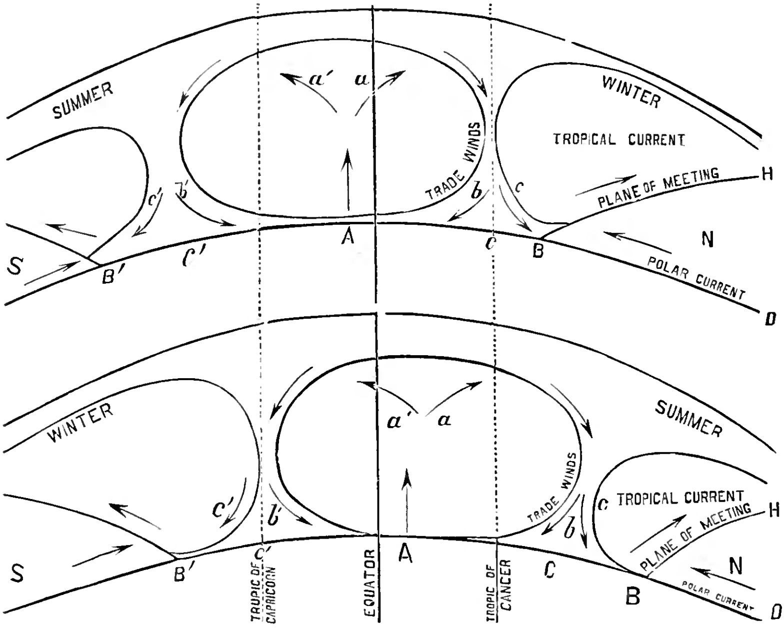

FIG. 1.—ATMOSPHERIC CURRENTS.

The inclination of the plane of meeting, or the slope of the tropi-

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[1] As shown at *B* in the diagram.

[2] From *B* to *D*.

cal current over the polar, varies with the seasons and local circumstances. In winter the slope between the two currents is very gradual, as there is less difference of temperature, and less power of resistance between them. The warm current passes over the cold at a gentle inclination (as represented by the line *B H* in Fig. 1); and thus the horizontal or geographical extent of the storm beneath it—from *B* to *D*—which is the region of low barometer, is much enlarged, and sometimes its oscillations extend or move over several hundred miles.

In summer, however, the difference of temperature between the two currents, and their power of resistance, are greater, and when they meet they bank up against each other with more momentum and force, and the plane of meeting or conflict is often very steep and sometimes almost vertical (as indicated by *B H* in Fig. 2). Hence, the geographical extent of a storm in summer is much less than in winter, and the region of low barometer which moves with it is correspondingly small.

CLOUDS THE PRECURSORS OF STORMS.—Whenever a warm current of air, saturated with moisture, meets or mingles with a cold current, the invisible moisture of the warm air is condensed into visible vapor or clouds. As storms are produced by the movements and conflicts of warm and cold currents of air, the formation of clouds always indicates to the observer the region in the atmosphere where such movements are taking place, which would otherwise be invisible. Clouds, therefore, are the invariable precursors of storms, and the kind of clouds formed will indicate the kind of storm or atmospheric movements which produce them.

This general fact, however, does not apply to deserts, where the moisture of the warm air is condensed and precipitated before it meets the cooler air, and hence rain-clouds are seldom or never formed by the sand-storms of deserts.

CLASSIFICATION OF CLOUDS.—Whenever, on account of some topographic circumstances, the sun heats any locality on the surface of the earth more than the surrounding region, a gentle current or column of heated air rises, and its invisible moisture is condensed into small masses of clouds called *cumuli*, which spread and produce the mottled appearance commonly known as "mackerel sky," as indicated at 1 in the accompanying illustration (Fig. 2).

But when, as is frequently the case in summer, a valley or plain, or island, or any other place, is much more highly heated by the sun than the surrounding region, the heated air over such locality rises more rapidly and with more ascensional momentum; and, as it reaches the higher and cooler regions of the atmosphere, its moisture is condensed into large rounded volumes, or mountain-like masses of *cumulus* clouds, as indicated at 2 in the illustration. Such *cumulus* clouds always precede and characterize a local summer storm or shower.

When the warm horizontal current from the south, as in winter, meets with the cold current from the north, it slopes upward over the cooler current, and forms stripes or bands of *stratus* clouds along the horizon, as shown in Fig. 3.

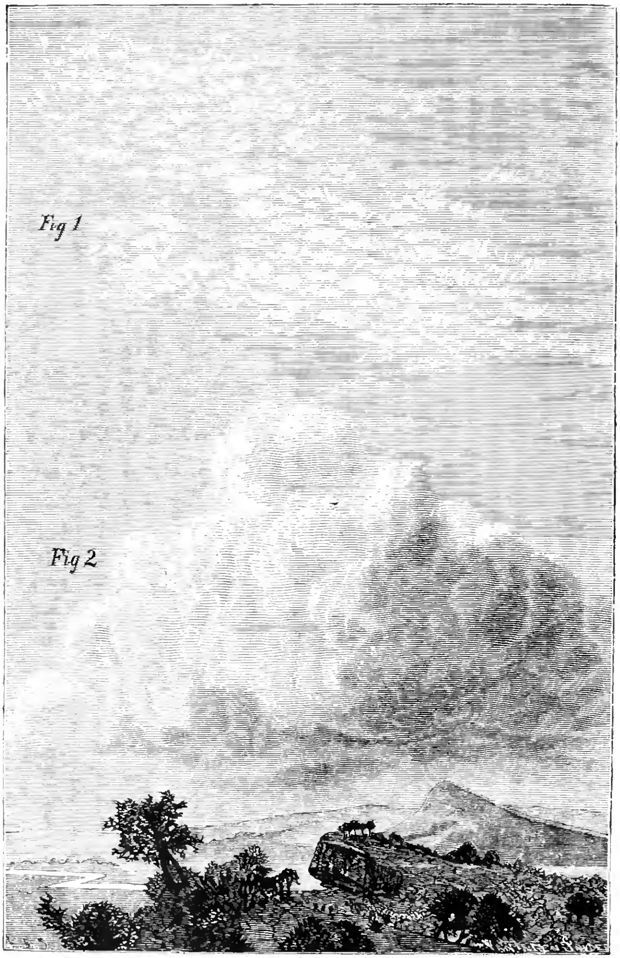

Fig. 2.—Cumulus Clouds.

These *stratus* clouds indicate to the observer the fact that a warm current is coming northward.

When in summer a cool current is moving southward, it encounters the warm equatorial or tropical current, which again glides upward and over it, and forms horizontal bands of *stratus* clouds along the upper line of contact, as in winter storms; but, in addition, the denser cold air from the north, moving with more momentum, will lift up the warm and saturated air from the tropics, and its moisture will be condensed into masses of *cumulus* clouds banked up against the top of the cold current, and arranged over the horizontal *stratus* clouds. Thus is produced the combination of *cumulo-stratus* cloud, as represented in Fig. 4, and which is characteristic of progressive summer storms.

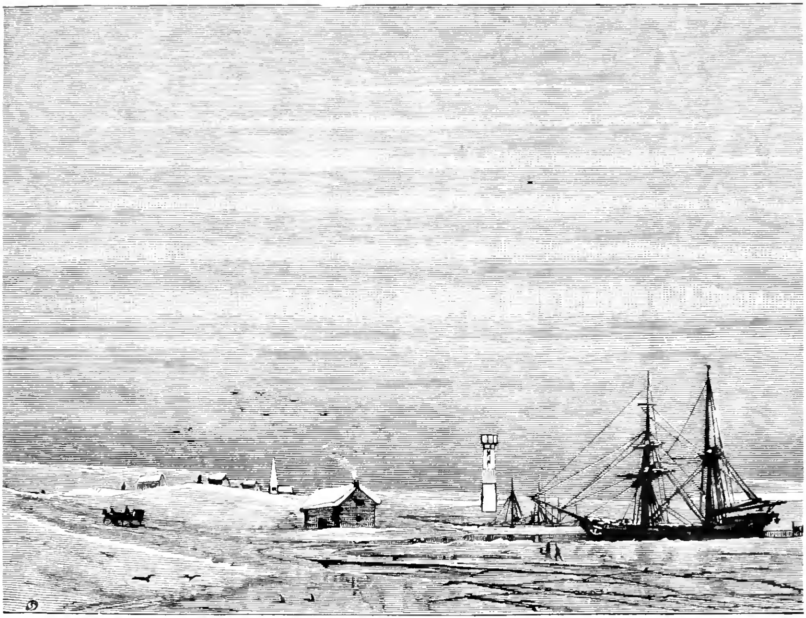

FIG. 3.—STRATUS CLOUDS.

To the tornado-cloud produced by a whirl of air, and resembling an inverted cone, Prof. Blasius gives the name of *conus*, which is both distinctive and appropriate.

These four typical classes of clouds—viz., cumulus, stratus, cumulo-stratus, and conus—indicate and characterize the four different classes of storms.

PREDICTION OF STORMS.—With the foregoing facts and classifications in view, Prof. Blasius's method of predicting the approach of storms, "by their embodiments the clouds," can be verified by any careful observer of ordinary intelligence.

WINTER STORMS.—When in winter, while the wind is blowing from the north, thin, hazy bands or stripes of *stratus* clouds appear low in the southern horizon, it indicates that the warm current from the south is flowing northward, sloping over the polar current, and that the condensation of its vapor into clouds, by successive undulations, has commenced in the upper and colder regions of contact. More and more of these *stratus* clouds gradually appear, until they cover the entire southern sky and reach the zenith. This may require from twelve to twenty-four hours, or longer. Sometimes these clouds, before reaching the zenith, will recede and disappear beneath the southern horizon. This indicates a backward oscillation of the southern current, caused by the greater resistance of the polar current. But in such case the *stratus* clouds will reappear next day, or sooner, and uniting and, becoming denser, they will advance over the zenith, and cover the whole heavens, discharging rain, snow, or sleet, according to the thermal conditions present.

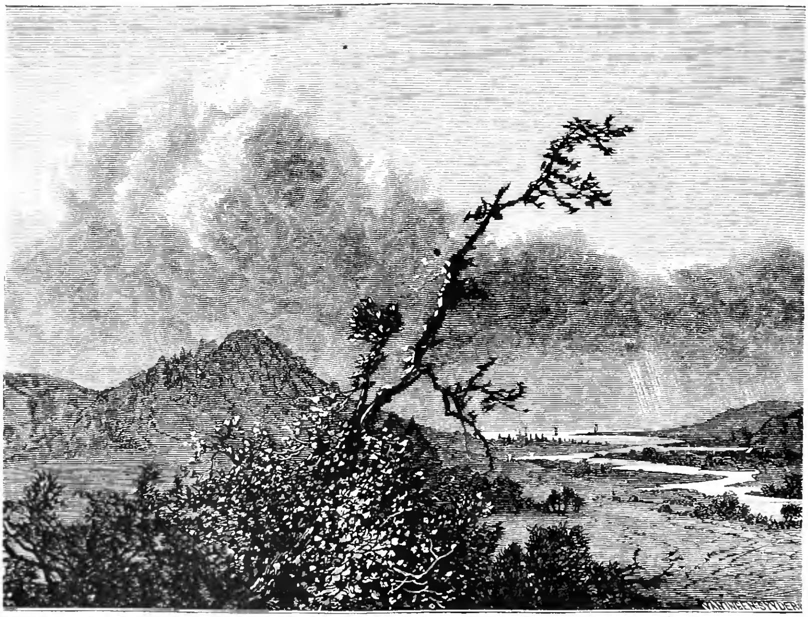

Fig. 4.—Cumulo-Stratus Clouds.

Thus, by observing the clouds, a northeast or winter storm may always be predicted from one to three days beforehand, while the barometer shows no change until the *stratus* clouds from the south have reached and passed over the zenith, when it begins to fall; but the thermometer indicates no change.

At this stage of the storm the wind from the north rises and blows more violently, while the clouds move northward against the wind, and the rain or snow, driven by the prevailing wind, comes down obliquely from the north. After some time the direction of the wind changes, and there is a calm. The air is warmer, the thermometer rises suddenly, the barometer has reached its lowest point, and the rain or snow falls vertically. This calm continues for a longer or shorter time, and the wind gradually changes until it comes from nearly or quite the opposite quarter from which it came at the beginning of the storm, and blows more powerfully than before. The barometer now rises again, but is not as high as before the storm, because it is in the tropical current which has reached the locality. If, now, the wind from the south, which has prevailed and driven back the northern current, continues in the same direction until the entire atmospheric area of the storm passes over the zenith northward, and the sky clears up from the south or southwest, as is generally the case in early autumn or late spring, then the next storm or change of weather will come from the north. But if the wind changes its direction again before the storm is over, as is mostly the case in mid-winter, and blows from the north, as it did at the beginning, until the entire atmospheric area of the storm is carried backward over the zenith, and the sky clears from the north, then the next storm or change of weather will come from the south, as described above. In this case the polar current has prevailed, the air is colder, the thermometer falls, the barometer rises higher than in the other case, and the atmospheric conditions existing before the storm are gradually reëstablished.

Summer Storms.—Before a progressive summer storm, the air is usually warm and sultry, the sky cloudless but somewhat dim, and a light southerly breeze is blowing. Suddenly the sound of distant rumbling thunder is heard, and large masses of dark *cumulus* clouds rise and arrange themselves on a long bank of *stratus* clouds in the northern or northwestern horizon. This is the *cumulo-stratus* combination of clouds which is the herald of a polar or progressive summer storm. Soon the south wind increases in violence, and drives clouds of dust before it. The thunder rolls, and lightning flashes more frequently. The clouds bank up higher and higher, and advance more slowly, until at last they become stationary. These are the ordinary indications of a violent progressive summer storm, which sometimes ends in a tornado.

Like a winter storm, it is produced by the meeting and conflict of the polar and tropical currents under greater differences of temperature and other conditions, and is therefore attended with more violent and complex phenomena than those of a winter storm. The changes of wind, and of the barometer and thermometer, during its development at any locality, are similar to those of a winter storm *in its return oscillation southward;* that is, these changes occur in a reverse order to those of a winter storm during the regular progress of the tropical current northward, in the same order as during its oscillation southward.

In most cases of this kind of summer storms, after the clouds have remained stationary for some time, discharged their rain and restored the disturbed equilibrium of the atmosphere, the polar current which produced it by moving southward oscillates back to the north again, and the storm at this locality is over—although similar phenomena and changes will be occasioned by it later at other localities over which it sweeps in its oscillation northward.

The *cumulo-stratus* cloud, which is the precursor of this kind of storm, can usually be observed only from one to eight hours, and, in some cases of the most violent kind, only about twelve hours before it will burst upon a place. Although these storms are the most dangerous and destructive—not unfrequently ending in tornadoes and hurricanes—the barometer is of no practical service in predicting it. This is explained by the fact that in such storms the plane of meeting of the two currents moves southward with its lower extremity, or region of lowest barometer, *in front*, while the plane itself is more or less inclined northward. Hence the barometer shows no change until this region of lowest barometer moves over it, when it suddenly falls; but it is then already in the most dangerous part of the storm, and its warning, therefore, comes too late; while the clouds, if properly observed, always give warning in time to provide against the dangers of such a storm.

TORNADOES.—This class of storms includes hailstorms, water-spouts, hurricanes, and all storms in which rotary and lateral motions are more or less combined. They are the most violent and destructive of all storms, as well as the most complicated and difficult to understand and explain. They are the offspring of progressive polar or summer storms, and in the temperate zone occur only during summer.

When in the development of a summer storm, as above described, the two conflicting currents attain a state of equal power or resistance, and thus balance each other, which is indicated when the dense *cumulus* clouds over the plane of conflict become stationary, then the storm is at its crisis. The air within the region of conflict is compressed and very sultry, and this condition is always felt before a tornado by persons within its area. If, now, during this critical stage of the storm, no topographic or other disturbance of its tension take place in its plane of meeting, a return oscillation of the polar current northward will set in, and the storm will gradually clear away. But if, in this crisis of the storm and during this high state of compression and resistance, either current becomes stronger, and forces back the other over some hill or valley, or if some other obstruction or configuration of the surface of the earth breaks the tension or disturbs the resistance between the two currents at any point, so that the polar current will sink as in a valley, then the tropical current will suddenly rush into this depression and generate a succession of violent whirling and zig-zag motions along the diagonal of the two currents within the plane of conflict, as the waters of a dam would rush through a sudden break or depression in an embankment. This conclusion respecting the origin of tornadoes Prof. Blasius reached after his careful study of the West Cambridge tornado of 1851, and it was subsequently confirmed by the facts and phenomena connected with the tornado of Iowa and Illinois, in May, 1873, as obtained from the report of the

United States Signal Service for that year, as well as by those of other tornadoes.

The characteristic cloud of a tornado is the *conus*, which appears first above as a dense, dark disk, and is formed by the whirl of the tropical current rushing into the depression of the polar current which starts the tornado, and it is enlarged and lengthened by alternate and rapid condensations above and below, as the tropical air whirls and zigzags along the diagonal of conflict, until sometimes the *conus* above and below unite—as in the case of water-spouts at sea—and a rotating column of mingled air, dense cloud, dust, or water—as the case may be—is thus formed, and sweeps along the plane of meeting between the opposing currents, and beneath the bank of *cumulus* clouds which mark the area of a tornado's path of destruction.

The *conus* cloud, however, as above described, is only formed when the tornado has already commenced, and is therefore of no use to indicate its occurrence beforehand.

But when the dark and dense masses of *cumulus* clouds in a summer storm cease moving forward or laterally, but bank up higher and higher, and there is great commotion among them, and when there is an oppressive sultriness about the air, these phenomena always indicate that the suspended storm is in a crisis or condition to generate a tornado, in case some local obstruction or other cause disturb the equilibrium of resistance between the two conflicting currents.

SCIENTIFIC ASPECTS.—The condensed result of modern meteorological science is the general fact announced by Prof. Buys-Ballot, of Utrecht, that "*the wind always blows from the place of highest to that of lowest barometer*, turning by the rotation of the earth to the right on the northern hemisphere, and to the left on the southern hemisphere." This is known as "Ballot's Law," and is the chief basis of all scientific weather predictions at the present day.

The first part of this law, given in italics, is found to be universally correct. The second part, however, has many exceptions, and is as often "honored in the breach as in the observance;" for, in polar storms, the winds from the northern semicircle do not conform to it.

Among other definite results attained by barometric observations and deduced from Ballot's law, is the fact that the rain-area of a storm extends over that of lowest barometer and also surrounds it. The isobars, or elliptic lines, of equal barometer, surround the area of lowest barometer, and the most distant isobar marks the limit of the region of low barometer, and may be regarded as the boundary between the regions of high and low barometer. The gradients indicate the differences of pressure between the isobars on a line extending at right angles from that of highest to that of lowest barometer.

The shape of the area of *lowest* barometer in a progressive storm is that of an irregularly elongated ellipse, moving sideways, or in the direction of its shortest diameter; and the gradients are found to be much more steep on the southward than on the northward side of this area; from which it follows that the rain-area is much less on the southward than on the northward side of a progressive storm.

All the atmospheric changes and phenomena above stated result from the same general cause, but under different conditions and circumstances. This cause is the meeting of the polar and tropical currents in their movements northward and southward, to restore a disturbed equilibrium in the atmosphere toward the equator or the poles.

Applying this theory in brief explanation of the facts stated in connection with Ballot's law, we find the area of *lowest* barometer at the place where the two currents meet on the surface of the earth. It is produced by the obliquely upward movement of the tropical current over the polar current, and by its rising more or less vertically in the vicinity of contact, after its horizontal progress northward has been checked by encountering the polar current. This oblique and upward movement of the tropical current diminishes the atmospheric pressure there, as shown by the barometer, and produces that depressing calm which is always felt by persons in any locality where this meeting of currents takes place, or over which its area moves or oscillates during the continuance of a storm. The elongated, elliptical shape of this area is accounted for by the fact that it is the narrow space between the two currents where they meet, and extends eastward and westward between them. It is rounded at the ends or margins of the currents, where the wind, in accordance with Ballot's law, blows inward toward the centre line of contact, which is also the centre line of lowest barometer. And, as the two currents force each other backward and forward during a storm, they necessarily carry along the elliptical space between them, and thus its movements in the direction of its shorter axis are accounted for.

The rain-area, or that of low barometer, which surrounds the elliptical region of lowest barometer where the currents meet on the surface, as just explained, extends horizontally beneath the plane of meeting, which is inclined northward. It is produced chiefly by the oblique and upward movement of the tropical current over the polar.

The gradients, or different degrees of pressure within the rain-area, are caused by the same upward movement of the tropical current over the polar, in connection with the constantly-varying heights or depths of both polar and tropical air, which are vertically above the space beneath the inclined plane from the region of lowest to that of highest barometer northward; and the steeper or more abrupt gradients southward are explained by the fact that when the tropical current meets the polar current it is suddenly checked, and while a portion of it moves obliquely over the polar current, as stated, another portion of it rises, more or less vertically, for some distance around the vicinity of contact, and the pressure is thus more suddenly diminished on the southward side of this area of low barometer than on the northward, where it slopes more gradually beneath the inclined plane of meeting, as above explained.

For obvious reasons, the region of high barometer is within the polar current before it meets the tropical, and also within the tropical current before it is disturbed, or its horizontal movement checked by meeting the polar current; but the barometer is highest in the polar current, because it is colder and denser.

In addition to the foregoing facts which barometric observations have established, this theory of opposing currents explains a great many other aërial problems and phenomena which have not heretofore been adequately accounted for. Among these are the real causes of different kinds of storms and how they originate; why they move forward and backward, carrying the lines and areas of high and low barometer, of isobars and gradients, with them, and why they cease; why the barometer indicates the approach of some storms in advance, but is useless in others; why it falls in some storms but rises in others; why a progressive storm travels *against* the prevailing wind, and why the wind changes during its progress; why there is a region of calm, and why the wind is stronger around this region of calm. It explains how snow-storms change to rain, or sleet and rain, and why it falls obliquely toward the direction from which the storm is coming; also why in some storms the rain falls in advance of the area of low barometer and in the rear of it in others. It accounts for the origin of tornadoes, water-spouts, hail-storms, and all other whirling storms, and explains why these always move in an eastward direction on our continent. It explains why the rain-areas of winter storms are more extended than those of summer, why their approach is slower and their continuance longer, and why they produce sudden changes of temperature in their progress over any place. It greatly simplifies and corrects previous explanations respecting the formation of different kinds of clouds, and accounts for the development of electricity both in summer and in winter storms.

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# ORDEALS AND OATHS.

By EDWARD B. TYLOR.

IN primitive stages of society, the clannish life of rude tribes may well have been more favorable to frank and truthful relations between man and man than our wider and looser social intercourse can be. Yet one can see, from the habits of modern savages, that already in early savage times society was setting itself to take measures against men who broke faith to save themselves from harm or to gain some coveted good. At the stage of civilization where social order was becoming regular and settled, the wise men turned their minds to devise guarantees stronger than mere yes and no. Thus the ordeal and the oath were introduced, that wrong-doing should not be concealed or denied, that unrighteous claims should not be backed by false witness, and that covenants made should not be broken.

The principles on which these ordeals and oaths were invented and developed may to this day be plainly made out. It is evident that the matter was referred to the two intellectual orders of early times, the magicians and the priests. Each advised after the manner of his own profession. The magician said, "With my symbols and charms I will try the accused, and bind the witness and the promiser." The priest said, "I will call upon my spirits, and they shall find out the hidden thing, and punish the lie and the broken vow." Now, magic and religion are separate in their nature and origin. *Magic* is based on a delusive tendency arising out of the association of ideas, namely, the tendency to believe that things which are ideally connected in our minds must therefore be really connected in the outer world. *Religion* is based on the doctrine of spiritual beings, souls, demons, or deities, who take cognizance of men and interpose in their affairs. It is needful to keep this absolute distinction clear in our minds, for on it depends our finding our mental way through a set of complicated proceedings, in which magical and religious elements have become mixed in the most intricate manner. Well they might, considering how commonly the professions of sorcerer and priest have overlapped so as even to be combined in one and the same person. But it seems, from a general survey of the facts of ordeals and oaths, that on the whole the magical element in them is earliest and underlying, while the religious element is apt to come in later in history, often only taking up and consecrating some old magical process.

In the series of instances to be brought into view, this blending of the religious with the magical element will be repeatedly observable. It will be seen also that the ordeal and the oath are not only allied in their fundamental principles, but that they continually run into one another in their use. Oaths, we shall see, may be made to act as ordeals, and ordeals are brought in as tests of oaths. While recognizing this close connection, it will be convenient to divide the two and take them in order according to their practical application, ordeals being proceedings for the discovery of wrong-doers, while oaths are of the nature of declarations of undertakings.

The association of ideas which serves as a magical basis for an ordeal is quite childish in its simplicity. Suppose it has to be decided which of two men has acted wrongfully, and appeal is had to the ordeal. There being no evidence on the real issue, a fanciful issue is taken instead, which can be settled, and the association of ideas does not rest. Thus in Borneo, when two Dyaks have to decide which is in the right, they have two equal lumps of salt given them to drop together into water, and the one whose lump is gone first is in the wrong. Or they put two live shell-fish on a plate, one for each disputant, and squeeze lime-juice over them, the verdict being given according to which man's champion-mollusk moves first. This reasoning is such as any child can enter into. Among the Sandwich-Islanders, again, when a thief had to be detected, the priest would consecrate a dish of water, and the suspected persons, one by one, held their hands over it, till the approach of the guilty was known by the water trembling. Here the connection of ideas is plain. But we may see it somewhat more fully thought out in Europe, where the old notion remains on record that the executioner's sword will tremble when a thief draws near, and even utter a dull clang at the approach of a murderer.

Starting with the magical ordeal, we have next to notice how the religious element is imported into it. Take the ordeal of the balance, well known to Hindoo law. A rude pair of scales is set up with its wooden scale-beam supported on posts; the accused is put in one scale, and stones and sand in the other to counterpoise him; then he is taken out, to be put in again after the balance has been called upon to show his guilt by letting him go down, or his innocence by raising him up. This is pure magic, the ideal weight of guilt being by mere absurd association of ideas transferred to material weight in a pair of scales. In this process no religious act is essential, but in practice it is introduced by prayers and sacrifices, and a sacred formula appealing to the great gods who know the walk of men, so that it is considered to be by their divine aid that the accused rises or falls at once in material fact and moral metaphor. If he either goes fairly up or down the case is clear. But a difficulty arises if the accused happens to weigh the same as he did five minutes before, so nearly at least as can be detected by a pair of heavy wooden scales which would hardly turn within an ounce or two. This embarrassing possibility has in fact perplexed the Hindoo lawyers not a little. One learned pundit says, "He is guilty, unless he goes right up!" A second suggests, "Weigh him again!" A third distinguishes with subtlety, "If he weighs the same he is guilty, but not so guilty as if he had gone right down!" The one only interpretation that never occurs to any of them is, that sin may be an imponderable. We may smile at the Hindoo way of striking a moral balance, but it should be remembered that a similar practice, probably a survival from the same original Aryan rite, was kept up in England within the last century. In 1759, near Aylesbury, a woman who could not get her spinning-wheel to go round, and naturally concluded that it had been bewitched, charged one Susannah Haynokes with being the witch. At this Susannah's husband was indignant, and demanded that his wife should be allowed to clear herself by the customary ordeal of weighing. So they took her to the parish church, stripped her to her under garments, and weighed her against the church Bible; she outweighed it, and went home in triumph. Here the metaphor of weighing is worked in the opposite way to that in India, but it is quite as intelligible, and not a whit the worse for practical purposes. For yet another case, how an old magical process may be afterward transformed by bringing in the religious sanction, we may look at the ancient classic sieve and shears, the sieve being suspended by sticking the points of the open shears into the rim, and the handles of the shears balanced on the forefingers of the holders. To discover a thief, or a lover, all that was required was to call over all suspected names, till the instrument turned at the right one. In the course of history, this childish divining-ordeal came to be Christianized into the key and Bible; the key, of course, to open the secret, the Bible to supply the test of truth. For a thief-ordeal, the proper mode is to tie in the key at the verse of the 50th Psalm, "When thou sawest a thief, then thou consentedst with him;" and then, when the names are called over, at the name of the guilty one the instrument makes its sign by swerving or turning in the holders' hands. This is interesting, as being almost the only ordeal which survives in common use in England; it may be met with in many an out-of-the-way farmhouse. It is some years since English rustics have dared to "swim" a witch, that is, to put in practice the ancient water-ordeal, which our folk-lore remembers in its most archaic Aryan form. Its essential principle is as plainly magical as any: the water, being set to make the trial, shows its decision by rejecting the guilty, who accordingly comes up to the surface. Our ancestors, who did not seize the distinction between weight and specific gravity, used to wonder at the supernatural power with which the water would heave up a wicked fellow, even if he weighed sixteen stone.

Mediæval ordeals, by water or fire, by touch of the corpse, or by wager of battle, have fallen to mere curiosities of literature, and it is needless to dwell here on their well-known picturesque details, or to repeat the liturgies of prayer or malediction said or sung by the consecrating priests. It is not by such accompanying formulas, but by the intention of the act itself, that we must estimate the real position of the religious element in it. Nowhere is this so strong as in what may be called the ordeal by miracle, where the innocent by divine help walks over the nine red-hot ploughshares, or carries the red-hot iron bar in his hand, or drinks a dose of deadly poison, and is none the worse for it; or, in the opposite way, where the draught of harmless water, cursed or consecrated by the priests, will bring, within a few days, dire disease on him or her who, being guilty, has dared to drink of it.

Looking at the subject from the statesman's point of view, the survey of the ordeals of all nations and ages enables us to judge with some certainty what their practical effect has been for evil or good.

Their basis being mere delusive imagination, when honestly administered, their being right or wrong has been matter of mere accident. It would, however, be a mistake to suppose that fair-play ever generally prevailed in the administration of ordeals. As is well known, they have always been engines of political power in the hands of unscrupulous priests and chiefs. Often it was unnecessary even to cheat, when the arbiter had it at his pleasure to administer either a harmless ordeal like drinking cursed water, or a deadly ordeal by a dose of aconite or physostigma. When it comes to sheer cheating, nothing can be more atrocious than this poison-ordeal. In West Africa, where the Calabar bean is used, the administerers can give the accused a dose which will make him sick, and so prove his innocence, or they can give him enough to prove him guilty, and murder him in the very act of proof; when we consider that over a great part of that great continent this and similar drugs usually determine the destiny of people inconvenient to the fetich-man and the chief—the constituted authorities of church and state—we see before us one efficient cause of the unprogressive character of African society. The famed ordeal by red-hot iron, also, has been a palpable swindle in the hands of the authorities. In India and Arabia the test is to lick the iron, which will burn the guilty tongue but not the innocent. Now, no doubt the judges know the secret that innocent and guilty alike can lick a white-hot iron with impunity, as any blacksmith will do, and as I have done myself, the layer of vapor in a spheroidal state preventing any chemical contact with the skin. As for the walking over red-hot ploughshares, or carrying a red-hot iron bar three paces in the palm of the hand, its fraudulent nature fits with the fact that the ecclesiastics who administered it took their precautions against close approach of spectators much more carefully than the jugglers do who handle the red-hot bars and walk over the ploughshares nowadays; and, moreover, any list of cases will show how inevitably the friend of the Church got off, while the man on the wrong side was sure to "lose his cause and burn his fingers." Remembering how Queen Emma in the story, with uplifted eyes, walked over the ploughshares without knowing it, and then asked when the trial was to begin, and how, after this triumphant issue, one-and-twenty manors were settled on the bishopric and church of Winchester, it may be inferred with some probability that in such cases the glowing ploughshares glowed with nothing more dangerous than daubs of red paint.

Almost the only effect of ordeals which can be looked upon as beneficial to society is, that the belief in their efficacy has done something to deter the credulous from crime, and still more often has led the guilty to betray himself by his own terrified imagination. Visitors to Rome know the great round marble mask called the Bocca della Verità. It is but the sink of an old drain; but many a frightened knave has shrunk from the test of putting his hand into its open "mouth of truth" and taking oath of his innocence, lest it should really close on him as tradition says it does on the forsworn. The ordeal by the mouthful of food is still popular in Southern Asia for its practical effectiveness: the thief in the household, his mouth dry with nervous terror, fails to masticate or swallow fairly the grains of rice. So in old England, the culprit may have failed to swallow the consecrated cor-snæd, or trial-slice of bread or cheese; it stuck in his throat, as in Earl Godwin's in the story. To this day the formula, "May this mouthful choke me if I am not speaking the truth!" keeps up the memory of the official ordeal. Not less effective is the ordeal by curse, still used in Russia to detect a thief. The *babushka*, or local witch, stands with a vessel of water before her in the midst of the assembled household, and makes bread-pills to drop in, saying to each in order, "Ivan Ivanoff, if you are guilty, as this ball falls to the bottom, so your soul will fall into hell." But this is more than any common Russian will face, and the rule is that the culprit confesses at sight. This is the best that can be said for ordeals. Under their most favorable aspect, they are useful delusions or pious frauds. At worst they are those wickedest of human deeds, crimes disguised behind the mask of justice. Shall we wonder that the world, slowly trying its institutions by the experience of ages, has at last come to the stage of casting out the judicial ordeal; or shall we rather wonder at the constitution of the human mind, which for so many ages has set up the creations of delusive fancy to hold sway over a world of facts?

From the ordeal we pass to the oath. The oath, for purposes of classification, may be best defined as an asseveration made under superhuman penalty, such penalty being (as in the ordeal) either magical or religious in its nature, or both combined. Here, then, we distinguish the oath from the mere declaration, or promise, or covenant, however formal. For example, the covenant by grasping hands is not in itself an oath, nor is even that wide-spread ancient ceremony of entering into a bond of brotherhood by the two parties mixing drops of their blood, or tasting each other's. This latter rite, though often called an oath, can under this definition be only reckoned as a solemn compact. But when a Galla of Abyssinia sits down over a pit covered over with a hide, imprecating that he may fall into a pit if he breaks his word, or when in our police-courts we make a Chinaman swear by taking an earthen saucer and breaking it on the rail in front of the witness-box, signifying, as the interpreter then puts it in words, "If you do not tell the truth, your soul will be cracked like this saucer," we have here two full oaths, of which the penalty, magical or religious, is shown in pantomime before us. By-the-way, the English judges who authorized this last sensational ceremony must have believed that they were calling on a Chinaman to take a judicial oath after the manner of his own country; but they acted under a mistake, for in fact the Chinese use no oaths at all in their law-courts. Now, we have to distinguish these real oaths from mere asseverations, in which emphatic terms, or descriptive gestures, are introduced merely for the purpose of showing the strength of resolve in the declarer's mind. Where, then, does the difference lie between the two? It is to be found in the incurring of supernatural penalty. There would be no difficulty at all in clearing up the question, were it not that theologians have set up a distinction between oaths of imprecation and oaths of witness. Such subtilties, however, looked at from a practical point of view, are seen to be casuistic cobwebs which a touch of the rough broom of common-sense will sweep away. The practical question is this: does the swearer mean that by going through the ceremony he brings on himself, if he breaks faith, some special magic harm, or divine displeasure and punishment? If so, the oath is practically imprecatory; if not, it is futile, wanting the very sanction which gives it legal value. It does not matter whether the imprecation is stated or only implied. When a Bedouin picks up a straw, and swears by him who made it grow and wither, there is no need to accompany this with a homily on the fate of the perjured. This reticence is so usual in the world, that as often as not we have to go outside the actual formula and ceremony to learn what their full intention is.

Let us now examine some typical forms of oath. The rude natives of New Guinea swear by the sun, or by a certain mountain, or by a weapon, that the sun may burn them, or the mountain crush them, or the weapon wound them, if they lie. The even ruder savages of the Brazilian forests, to confirm their words, raise the hand over the head or thrust it into their hair, or they will touch the points of their weapons. These two accounts of savage ceremony introduce us to customs well known to nations of higher culture. The raising of the hand toward the sky seems to mean here what it does elsewhere. It is in gesture calling on the heaven-god to smite the perjurer with his thunderbolt. The touching of the head, again, carries its meaning among these Brazilians almost as plainly as in Africa, where we find men swearing by their heads or limbs, in the belief that they would wither if forsworn; or, as when among the Old Prussians a man would lay his right hand on his own neck, and his left on the holy oak, saying, "May Perkun (the thunder-god) destroy me!" As to swearing by weapons, another graphic instance of its original meaning comes from Aracan, where the witness swearing to speak the truth takes in his hand a musket, a sword, a spear, a tiger's tusk, a crocodile's tooth, and a thunderbolt (that is, of course, a stone celt). The oath by the weapon not only lasted on through classic ages, but remained so common in Christendom that it was expressly forbidden by a synod; even in the seventeenth century, to swear on the sword (like Hamlet's friends in the ghost-scene) was still a legal oath in Holstein. As for the holding up the hand to invoke the personal divine sky, the successor of this primitive gesture remains to this day among the chief acts in the solemn oaths of European nations.

It could scarcely be shown more clearly with what childlike imagination the savage conceives that a symbolic action, such as touching his head or his spear, will somehow pass into reality. In connection with this group of oaths, we can carry yet a step further the illustration of the way men's minds work in this primitive stage of association of ideas. One of the accounts from New Guinea is that the swearer, holding up an arrow, calls on Heaven to punish him if he lies; but by turning the arrow the other way the oath can be neutralized. This is magic all over. What one symbol can do, the reverse symbol can undo. True to the laws of primitive magical reasoning, uncultured men elsewhere still carry on the symbolic reversal of their oaths. An Abyssinian chief, who had sworn an oath he disliked, has been seen to scrape it off his tongue and spit it out. There are still places in Germany where the false witness reckons to escape the spiritual consequences of perjury by crooking one finger, to make it, I suppose, not a straight but a crooked oath, or he puts his left hand to his side to neutralize what the right hand is doing. Here is the idea of our "over the left;" but so far as I know this has come down with us to mere schoolboy's shuffling.

It has just been noticed that the arsenal of deadly weapons by which the natives of Aracan swear, includes a tiger's tusk and a crocodile's tooth. This leads us to a group of instructive rites belonging to Central and North Asia. Probably to this day there may be seen in Russian law-courts in Siberia the oath on the bear's head. When an Ostiak is to be sworn a bear's head is brought into court, and the man makes believe to bite at it, calling on the bear to devour him in like manner if he does not tell the truth. Now, the meaning of this act goes beyond magic and into religion, for we are here in the region of bear-worship, among people who believe that this wise and divine beast knows what goes on, and will come and punish them. Nor need one wonder at this, for the idea that the bear will hear and come if called on is familiar to German mythology. I was interested to find it still in survival in Switzerland a few years ago, when a peasant-woman, whom a mischievous little English boy had irritated beyond endurance, pronounced the ancient awful imprecation on him, "The bear take thee!" (der Bär nimm dich!) Among the hill-tribes of India a tiger's skin is sworn on in the same sense as the bear's head among the Ostiaks. Rivers, again, which to the savage and barbarian are intelligent and personal divinities, are sworn by in strong belief that their waters will punish him who takes their name in vain. We can understand why Homeric heroes swore by the rivers, when we hear still among Hindoos how the sacred Ganges will take vengeance sure and terrible on the children of the perjurer. It is with the same personification, the same fear of impending chastisement from the outraged deity, that savage and barbaric men have sworn by sky or sun. Thus the Huron Indian would say in making solemn promise, "Heaven hears what we do this day!" and the Tunguz, brandishing a knife before the sun, would say, "If I lie, may the sun plunge sickness into my entrails like this knife." We have but to rise one stage higher in religious ideas to reach the type of the famous Roman oaths by Jupiter, the heaven-god. He who swore held in his hand a stone, praying that, if he knowingly deceived, others might be safe in their countries and laws, their holy places and their tombs, but he alone might be cast out, as this stone now—and he flung it from him. Even more impressive was the great treaty-oath, where the *pater patratus*, holding the sacred flint that symbolized the thunderbolt, called on Jove that if by public counsel or wicked fraud the Romans should break the treaty first—"In that day, O Jove, smite thou the Roman people as I here to-day shall smite this swine, and smite the heavier as thou art the stronger!" So saying, he slew the victim with the sacred stone.

These various examples may be taken as showing the nature and meaning of such oaths as belong to the lower stages of civilization. Their binding power is that of curses, that the perjurer may be visited by mishap, disease, death. But at a higher stage of culture, where the gods are ceasing to be divine natural objects like the Tiber or Ganges, or the sun or sky, but are passing into the glorified human or heroic stage, like Apollo or Venus, there comes into view a milder kind of oath, where the man enters into fealty with the god, whom he asks to favor or preserve him on condition of his keeping troth. Thus, while the proceeding is still an oath with a penalty, this penalty now lies in the perjurer's forfeiting the divine favor. To this milder form, which we may conveniently call the "oath of conditional favor," belong such classic phrases as "So may the gods love me!" (*Ita me Dii ament!*), "As I wish the gods to be propitious to me!" (*Ita mihi Deos velim propitios*). I call attention to this class of oaths, of which we shall presently meet with a remarkable example nearer home. We have now to take into consideration a movement of far larger scope.

Returning to the great first-mentioned class of savage and barbaric oaths, sworn by gestures or weapons, or by invocation of divine beasts, or rivers, or greater Nature-deities—the question now to be asked is, What is the nature of the penalties? It is, that the perjurer may be withered by disease, wounded, drowned, smitten by the thunderbolt, etc., all these being temporal, visible punishments. The state of belief to which the whole class belong is that explicitly described among the natives of the Tonga Islands, where oaths were received on the declared ground that the gods would punish the false-swearer here on earth. A name is wanted to denote this class of oaths, belonging especially to the lower culture; let us call them "mundane oaths." Now, it is at a point above the savage level in culture that the thought first comes in of the perjurer being punished in a world beyond the grave. This was a conception familiar to the Egyptians in their remotely ancient civilization. It was at home among the old Homeric Greeks, as when Agamemnon, swearing his mighty oaths, calls to witness, not only Father Zeus, and the all-seeing sun, and the rivers, and earth, but also the Erinnys who down below chastise the souls of the dead, whosoever shall have been forsworn. Not less plainly is it written in the ancient Hindoo "Laws of Manu"—"A man of understanding shall swear no false oath even in a trifling matter, for he who swears a false oath goes hereafter and here to destruction." To this higher stage of culture, then, belongs the introduction of the new "post-mundane" element into oaths. For ages afterward nations might still use either kind, or combine them by adding the penalty after death to that in life. But in the later course of history there comes plainly into view a tendency to subordinate the old mundane oath, and at last to suppress it altogether. How this came to pass is plain on the face of the matter. It was simply the result of accumulated experience. The continual comparison of opinions with facts could not but force observant minds to admit that a man might swear falsely on sword's edge or spear's point, and yet die with a whole skin; that bears and tigers were not to be depended on to choose perjurers for their victims, and that in fact the correspondence between the imprecation and the event was not real, but only ideal. How judgment by real results thus shaped itself in men's minds we may see by the way it came to public utterance in classic times, nowhere put more cogently than in the famous dialogue in the "Clouds" of Aristophanes. The old farmer Strepsiades asks, "Whence comes the blazing thunderbolt that Zeus hurls at the perjured?" "You fool," replies the Socrates of the play, "you smack of old Kronos's times—if Zeus smote perjurers, wouldn't he have been down on those awful fellows Simon, and Kleonymos, and Theoros? Why, what Zeus does with his bolt is to smite his own temple, and the heights of Sunium, and the tall oaks! Do you mean to say that an oak-tree can commit perjury?" What is said here in chaff full many a reasonable man in the old days must have said to himself in the soberest earnest, and, once said or thought, but one result could come of it—the result which history shows us did come. The venue of the judicial oath was gradually changed, till the later kind, with its penalties transferred from earth to the region of departed souls, remained practically in possession of the field.

As a point in the science of culture, which has hitherto been scarcely if at all observed, I am anxious to call attention to the historical stratification of judicial oaths, from the lowest stratum of mundane oaths belonging to savage or barbaric times, to the highest stratum of post-mundane oaths such as obtain among modern civilized nations. Roughly, the development in the course of ages may be expressed in the following two classifications:

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| Mundane | Oaths, | Curse. |
| Mixed | | Conditional Favor. |
| Post-Mundane | | Judgment. |

Though these two series only partly coincide in history, they so far fit that the judicial oaths of the lower culture belong to the class of mundane curse, while those of the higher culture in general belong to that of post-mundane judgment. Anthropologically, this is the most special new view I have here to bring forward. It forms part of a wider generalization, belonging at once to the science of morals and the science of religion. But, rather than open out the subject into this too wide field, we may do well to fix it in our minds by tracing a curious historical point in the legal customs of our own country. Every one knows that the modes of administering a judicial oath in Scotland and in England are not the same. In Scotland, where the witness holds up his hand toward heaven, and swears to tell the truth as he shall answer to God at the day of judgment, we have before us the most explicit possible example of a post-mundane oath framed on Christian lines. In contrasting this with the English judicial oath, we first notice that our acted ceremony consists commonly in taking a New Testament in the hand and kissing it. Thus, unlike the Scotch oath, the English oath is sworn on a *halidome* (Anglo-Saxon, *hâligdōm;* German, *heiligthum*), a holy or sacred object. Many writers have fallen into confusion about this word, mystifying it into sacred judgment or "holy doom;" but it is a perfectly straightforward term for a sanctuary or relic, as "On tham haligdome swerian"—to swear by the relic. Now, this custom of swearing on a halidome belongs to far pre-Christian antiquity, one famous example being when Hannibal, then a lad of nine years old, was brought by his father to the altar and made to swear, by touching the sacred things (*tactis sacris*), that when he grew up he would be the enemy of Rome. In classical antiquity the sacred objects were especially the images and altars of the gods, as it is put in a scene in Plautus, "Touch this altar of Venus!" The man answers, "I touch it," and then he is sworn. When this ancient rite came into use in early Christian England, the object touched might be the altar itself, or a relic-shrine like that which Harold is touching with his right forefinger in the famous scene in the Bayeux tapestry, or it might be a missal, or a book of the gospels. In modern England a copy of the New Testament has become the recognized halidome on which oaths are taken, and the practice of kissing it has almost supplanted the older and more general custom of touching it with the hand.

Next, our attention must be called to the remarkable formula in which (in England, not in Scotland) the invocation of the Deity is made, "So help me God!" or "So help you God!" Many a modern Englishman puzzles over this obscure form of words. When the question is asked what the meaning of the oath is, the official interpretation practically comes to saying that it means the same as the Scotch oath. But neither by act nor word does it convey this meaning. So obvious is the discrepancy between what is considered to be meant and what is actually done and said, that Paley, remarking on the different forms of swearing in different countries, does not scruple to say that they are "in no country in the world, I believe, worse contrived either to convey the meaning, or impress the obligation of an oath, than in our own."

This remark of Paley's aptly illustrates a principle of the science of culture which cannot be too strongly impressed on the minds of all who study the institutions of their own or any other age. People often talk of mystic formulas and mystic ceremonies. But, the more we study civilization in its earlier stages, the more we shall find that formulas and ceremonies, both in law and in religion, are as purposeful and business-like as can be, if only we get at them anywhere near their origin. What happens afterward is this, that, while men's thoughts and wants gradually change, the old phrases and ceremonies are kept up by natural conservatism, so that they become less and less appropriate, and then, as their meaning falls away, its place is apt to be filled up with mystery. Applying this principle to the English-oath formula, we ask what and where it originally was. It was Teutonic-Scandinavian, for, though corresponding formulas are known in Latin (*Ita me adjuvet Deus*) and in Old French (*Ce m'ait Diex*, etc.), these are shown by their comparatively recent dates to be mere translations of the Germanic originals. Now, although ancient English and German records fail to give the early history of the phrase, this want is fortunately supplied by a document preserved in Iceland. Some while after the settlement of the island by the Northmen, but long before their conversion to Christianity, the settlers felt the urgent need of a code of laws, and accordingly Ulfliot went to Norway for three years to Thorleif the Wise, who imparted to him his legal lore. Ulfliot went to Norway A. D. 925, so that the form of judicial oath he authorized, and which was at a later time put on record in the Icelandic Landnâmabôk, may be taken as good and old in Norse law. Its pre-Christian character is, indeed, obvious from its tenor. The halidome on which it was sworn was a metal arm-ring, which was kept by the godhi or priest, who reddened it with the blood of the ox sacrificed, and the swearer touching it said, in words that are still half English: "Name I to witness that I take oath by the ring, law-oath, so help me Frey, and Niördh, and almighty Thor (hialpi mer svâ Freyr, ok Niördhr, ok hinn almâttki Âss) as I shall this suit follow or defend, or witness bear or verdict or doom, as I wit rightest and soothest and most lawfully," etc. Here, then, we have the full and intelligible formula which must very nearly represent that of which we keep a mutilated fragment in our English oath. So close is the connection, that two of the gods referred to, Frey and Thor (who is described as the almighty god), are the old English gods whose names we commemorate in Friday and Thursday. The formula belongs, with the classic ones lately spoken of, to the class of oaths of conditional favor, "*so* help me *as* I shall do rightly," while Frey and Niördh are gods whom a Norse warrior would ask for earthly help, but who would scarcely concern themselves with his soul after death. It is likely that the swearer was not indeed unmindful of what the skalds sang of Naströnd, the strand of corpses, that loathly house arched of the bodies of huge serpents, whose heads, turned inward, dripped venom on the perjurers and murderers within. But the primary formula is, as I have said, that of the oath of conditional favor, not of judgment. With the constituents of the modern English oath now fairly before us, we see that its incoherence, as usual in such cases, has an historical interpretation. What English law has done is to transplant from archaic fetich-worship the ceremony of the halidome or consecrated object, and to combine with this one-half of a pre-Christian formula of conditional favor, without the second half which made sense of it. Considering that to this combination is attached a theological interpretation which is neither implied in act nor word, we cannot wonder if in the popular mind a certain amount of obscurity, not to say mystery, surrounds the whole transaction. Nevertheless, we may well deprecate any attempt to patch up into Scotch distinctness and consistency the old formula, which will probably last untouched so long as judicial oaths shall remain in use in England.

Being in the midst of this subject, it may not be amiss to say a few words upon old and new ideas as to the administration of oaths to little children. The Canon Law expressly forbade the exacting of an oath from children under fourteen—*pueri ante annos XIV non cogantur jurare.* This prohibition is derived from yet earlier law. The rough old Norsemen would not take oaths from children, as comes out so quaintly in the *saga* of Baldur, where the goddess made all the beasts and birds and trees swear they would not harm him, but the little mistletoe only she craved no oath from, for she thought it was too young. Admitting the necessity of taking children's evidence somehow, the question is how best to do it. In England it must be done on oath, and for this end there has arisen a custom in our courts of putting the child through an inquisition as to the theological consequences of perjury, so as usually to extract from it a well-known definition which the stiffest theologian will not stand to for a moment if put straight to him, but which is looked upon as a proper means for binding the conscience of a little child.[1] Moreover, children

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[1] Two illustrative cases are given me by a friend learned in the law. In court lately, a little girl was asked the usual preliminary question as to the consequence of swearing

in decent families learn to answer plain questions some years before they learn to swear, and material evidence is often lost by the child not having been taught beforehand the proper answers to make when questioned as to the nature of an oath. I heard of a case only lately, which was expected to lead to a committal on a charge of murder, and where an important point rested on the evidence of a young lad who was, to all appearance, truthful, but who did not satisfy the bench that he understood the nature of an oath. Those in whom the ceremony of swearing a child arouses the feeling of physical repugnance that it does in myself, may learn with interest a fact as yet little known in England, and which sufficiently justifies my bringing forward the subject. Hearing that there was something to be learned from Germany, I applied to the eminent jurist, Dr. Gneist, of Berlin, and hear from him that under the new German rules of procedure, which are expected shortly to come into force, the evidence of children under sixteen may be received without oath, at the discretion of the judge. In these days there is a simple rule which an Englishman will do well to act up to, and that is, "Don't be beaten by a German!" Let us live in the heartiest fellowship with the Germans, and never let them get ahead of us if we can help it. In this matter of children's legal evidence, they are fairly leaving us behind, by introducing a plan which is at once more humane and more effective than ours.

If, now, looking at the subject as one of practical sociology, we consider what place the legal oath has filled in savage, barbaric, and civilized life, we must adjudge to it altogether higher value than to the ordeal. At certain stages of culture it has been one of the great forces of society. There was a time when Lycurgus could tell the men of Athens that the oath was the very bond that held the democracy together. There was a time when, as Montesquieu insists, an oath was so binding on the minds of the Romans, that for its observance they would do more than even patriotism or love of glory could draw them to. In our own day, its practical binding power is unmistakable over the consciences of a numerous intermediate class of witnesses, those who are neither truthful nor quite reckless, who are without the honesty which makes a good man's oath superfluous, who will indeed lie solemnly and circumstantially, but are somewhat restrained from perjury by the fear of being, as the old English saying has it, "once forsworn, ever forlorn." Though the hold thus given is far weaker than is popularly fancied, it has from time to time led

falsely, and answered in due form, "Please, sir, I should go to burning hell!" Unluckily, however, the unusual question was then put, how she knew that? which brought the reply, "Oh, please, another girl outside told me I was to say so!" It is bar tradition, though there may be no record in print, that years ago the most sarcastic of English judges put the whole matter in a nutshell. The question having been asked of a child witness, if she knew what would become of her when she died, she answered simply, "Don't know, sir!" whereupon the judge said, "Well, gentlemen, no more do I know—but the child's evidence cannot be taken."

legislators to use oaths, not merely in special and solemn matters, but as means of securing honesty in the details of public business. When this has been done, the consequences to public morals have been disastrous. There is no need to hunt up ancient or foreign proofs of this, seeing how conspicuous an instance is the state of England early in the present century, while it was still, as a contemporary writer called it, "a land of oaths," and the professional perjurer plied a thriving trade. A single illustration will suffice, taken from the valuable treatise on Oaths, published in 1834, by the Rev. James Endell Tyler: "During the continuance of the former system of custom-house oaths, there were houses of resort where persons were always to be found ready at a moment's warning to take any oath required; the signal of the business for which they were needed was this inquiry, 'Any damned soul here?'" Nowadays this enormous excess of public oaths has been much cut down, and with the best results. Yet it must be evident to students of sociology that the world will not stop short at this point. The wider question is coming into view, What effect is produced on the every-day standard of truthfulness by the doctrine that fraudulent lying is in itself a minor offense, but is converted into an awful crime by the addition of a ceremony and a formula? It is an easily-stated problem in moral arithmetic; on the credit side, Government is able to tighten with an extra screw the consciences of a shaky class of witnesses and public officers; on the debit side, the current value of a man's word is correspondingly depreciated through the whole range of public and private business. As a mere sober student of social causes and effects, following along history the tendencies of opinion, I cannot doubt for a moment how the public mind must act on this problem. I simply predict that where the judicial ordeal is already gone, there the judicial oath will sooner or later follow. Not only do symptoms of the coming change appear from year to year, but its greatest determining cause is unfolding itself day by day before observant eyes, a sight such as neither we nor our fathers ever saw before.

How has it come to pass that the sense of the sanctity of intellectual truth, and the craving after its full and free possession, are so mastering the modern educated mind? This is not a mystery hard to unravel. Can any fail to see how in these latter years the methods of scientific thought have come forth from the laboratory and the museum to claim their powers over the whole range of history and philosophy, of politics and morals? Truth in thought is fast spreading its wide waves through the outside world. Of intellectual truthfulness, truthfulness in word and act is the outward manifestation. In all modern philosophy there is no principle more fertile than the doctrine so plainly set forth by Herbert Spencer—that truth means bringing our minds into accurate matching with the realities in and around us; so that both intellectual and moral truth are bound up together in that vast process of evolution whereby man is gradually brought into fuller harmony with the universe he inhabits. There need, then, be no fear that the falling away of such artificial crutches as those whose history I have here been tracing should leave public truth maimed and halting. Upheld by the perfect fitting of the inner mind to the outer world, the progress of truth will be firmer and more majestic than in the ancient days. If, in time to come, the grand old disputation before King Darius were to be reënacted, to decide again the question, "What is the strongest of all things?" it would be said, as then, that "Truth abides, and is strong for evermore, living and conquering from age to age." And the people as of old would say again with one voice, "Truth is great, and prevails!" [1]—*Advance-sheets of Macmillan's Magazine.*

## THE CHROMIS PATER-FAMILIAS.

By Dr. LORTET.

Up to the present we know but a small number of fishes which hatch their eggs and bring up their young in the cavity of the mouth or among the gills. Agassiz, during his voyage on the Amazonas, discovered one species. Afterward there was brought from China the macropod, the singular habits of which are now known to all the world. All these species belong to the great group of the *Labyrinthobranchiata;* and Agassiz supposes that the fishes of this order only can hatch their eggs in so abnormal a manner, thanks to the branchial pockets which allow of the eggs being easily kept in place. But the *Chromis*, of which we give a faithful representation, proves the assertion of Agassiz to be erroneous. The *Chromis pater-familias* has the gills disposed in simple laminæ; it is unprovided with any special apparatus for retaining the eggs or the young ones, and yet it brings up about 200 young in the mouth and gills. It is always the male that performs these functions of incubation. After the female has deposited the eggs in a depression of the sand or between the tufts of reeds, the male approaches and takes them by inhalation into the cavity of the mouth. From there some movement, the mechanism of which we have not been able to observe, sends them between the leaflets of the gills. The pressure exerted on the eggs by the branchial laminæ suffices to keep them in place. There, in the midst of the organs of respiration, the eggs undergo all their metamorphoses. The young ones grow rapidly, and soon appear much inconvenienced in their narrow prison. They leave it, not by the gills but through the opening by which the bronchial cavity communicates with the

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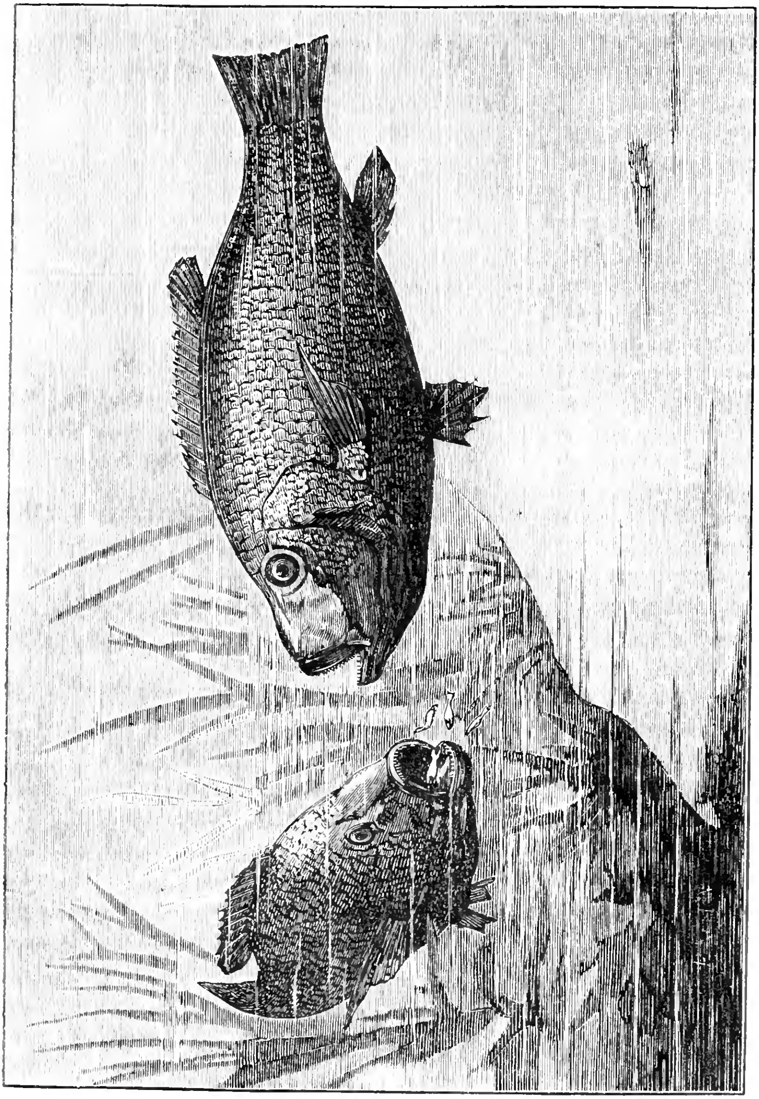
[1] 1 Esdras iv. 41: *μεγάλη ἡ ἀλήθεια, καὶ ὑπερισχύει—Magnas est veritas, et prævalet.*

mouth. Here they remain in great number, pressed against one another like the seeds of a pomegranate. The animal's mouth becomes so distended by the presence of this numerous progeny that actually the jaws cannot meet. The cheeks are swollen and the animal presents the strangest aspect. Some of the young, arrived at the perfect state, continue to live in the gills. All have the head directed toward the buccal opening of the father, the protecting cavity of which we have not seen them leave even for a moment. Though so numerous,



Chromis Pater-familias of Lake Tiberias.

they hold their ground very firmly, yet how they do so we have not discovered. Neither can we understand how the nursing father avoids swallowing his progeny; we are also ignorant at what period of their life the young ones leave the paternal mouth to live independently.

The *Chromis pater-familias* is 7 inches long by 1¾ inch thick. The teeth are very fine and sharp, disposed in several rows. The snout is obtuse, conical, the upper profile oblique. The nasal prominence is very conspicuous. The caudal fin is almost truncated. The soft rays of the dorsal reach to the beginning of the caudal. The length of the body, including the tail, is 4½ times its thickness. The snout is in length twice the diameter of the orbit. The mouth is slightly oblique, large, as wide as it is long. The teeth are slightly recurved, disposed in three or four rows, tinged with deep yellow at the free end. The first row presents 26 on each side of the upper maxillary. The fins show the number of rays following:

| | |
|---|---|
| Dorsal | 14 + 11 |
| Anal | 3 + 8 |
| Caudal | 16 |
| Pectoral | 12 |
| Ventral | 1 + 5 |

The lateral line comprises 32 scales disposed 20 + 12. The scales are cycloidal, their length greater than their breadth; three-fourths of their surface is covered by the succeeding scales. Color, olive-green on the back, barred with blue. The belly has a silvery lustre, with green and blue spots.

I caught this interesting species, with a net, on the 29th of April, 1875, in shallow water full of reeds, on the margin of Lake Tiberias, at a place called Ain-Tin, the ancient Capernaum. There are numerous warm springs there which unite to form a rather considerable stream. It is in these warm waters that the *Chromis* lives.—*La Nature.*

## BIGOTRY IN SCIENTIFIC CONTROVERSY.[1]

MANY edifying commonplaces might doubtless be written on the intellectual fermentation, if it may not rather be called confusion of the age. Nor can it be denied that tendencies supposed to have been long ago slain and sepulchred have risen again, and are asserting themselves with a hardihood which our fathers would have deemed impossible. When we find a scientific work—at any rate a work written by an eminent scientific man, and devoted to the dis-

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[1] "Lessons from Nature. By St. George Mivart, F. R. S." New York: D. Appleton & Co.

cussion of scientific questions—formally dedicated to a dignitary of the Catholic Church as a vindicator of the rights of conscience (!), we may well ask, not jeeringly but sadly, "What is truth?" We have witnessed of late brilliant progress in various departments of science; but we have also seen attacks made upon the very foundations of science. These onslaughts are increasing in frequency and in boldness. Metaphysicians and ecclesiastics are calling in question the inductive method, impugning the independence of Science, and seeking to reassert over her the authority of "the Church." The battles of the sixteenth century seem about to be repeated. And some, who might claim to be the heirs of Galileo, think it no ignominy to wear the livery of Bellarmin and Caccini.

When we first opened the book which has suggested our present article we fully expected to find an intellectual treat of the highest order: its subject is one on which a most valuable work might well be written, and few living men, indeed, are better qualified to undertake such a task than is Mr. Mivart. Anti-Darwinian polemics we awaited, but such criticism, if conducted on legitimate—that is, on purely scientific—principles, we should be among the first to welcome, well knowing that in any issue Science must be the gainer. Although believing in Evolution, we have never given to the hypothesis commonly known as "Darwinism" more than a qualified and provisional adhesion. While admitting that it has thrown a flood of light over some of the most difficult questions in natural history, and has brought into vital connection a previously incoherent mob of facts, and that it is still a powerful and valuable instrument in the hands of the inquirer, we cannot forget that it has its difficulties. Some of these we have, on former occasions, endeavored to point out. Hence we should cordially recognize any theory which should either supplement the doctrines of "Natural Selection" and "Sexual Selection," or modify them so as to get rid of their drawbacks and shortcomings. Nay, we should be well pleased to find them superseded altogether by a new hypothesis, adapted at once to the phenomena they have explained and the residues and anomalies which they have hitherto left unsolved. Such an hypothesis we thought Mr. Mivart might have produced, or at least have attempted; and the very attempt could scarcely be made, from a legitimate point of view, without leading to valuable results. Never were we more signally disappointed, although in these days the title of a book is often intended to conceal, rather than to reveal, its nature and object. The strange dedication was, in truth, but too ominous of the contents. The work we found was not constructive, but destructive. It consists of a series of attacks upon a number of men who have done good service in different branches of science, such as Darwin, Wallace, Huxley, Tyndall, Galton, Lubbock, Helmholtz, Oscar Schmidt—or who have dealt with methodology, such as Comte, Mill, Spencer, Lewes, etc. The doctrines of natural selection and sexual selection are indeed discussed, and a desperate effort is made to resuscitate the fast-fading notion of a "great gulf" between man and the lower animals. It is a curious fact that in the old natural history man is supposed to hold, in relation to other animals, a place very similar to that assigned by the Lavoisierian chemistry to oxygen in relation to the remaining elements. Unfortunately, in biology, passion, prejudice, and sophistry, play a more important part than they do in chemistry and physics. The discussion is based upon false principles. We all know the passage in which Mr. Wallace specifies the kind of controversy which alone can be recognized: "As his hypothesis is one which claims acceptance solely as explaining and connecting facts which exist in Nature, he expects facts alone to be brought to disprove it."[1] This method of discussion finds here comparatively little favor. Theories are tested by their supposed moral or religious bearings, or by their agreement with the author's *a priori* views. If we bring facts to prove the existence of reason in animals, we are told that we do not know what reason is; if we find in them evidences of moral life, it is said that we have "not even the faintest conception of what a moral nature is." If we show that they possess language, there follows the ready quirk that we confound emotional language with intellectual. That Mr. Mivart's own views of moral nature and of reason must be correct, no one, of course, is supposed to doubt; nor is the spirit of the argument sounder than its method. The author speaks, not as a judge calmly weighing the arguments on either side, and anxious merely that the truth should be ascertained, but as a passionate and eager prosecuting counsel, or rather as a *procureur du roi* (king's attorney), skillfully bringing forward every circumstance, every point—actual or inferred, relevant or irrelevant—which may in any wise damage the defendants, and with equal dexterity concealing whatsoever might tell in their favor. Deep personal hatred toward the "Agnostics" and their doctrines—the *odium theologicum* in its most malignant form—pervades the entire book. Mr. Mivart may doubtless be able to meet Mr. Darwin, Mr. Lewes, Mr. Spencer, or Dr. Huxley, on neutral ground or in private life, on terms of ordinary courtesy; but it is because the man is better and greater than his book. We find here nothing of that fine manly spirit expressed in the old adage, "Plato is my friend, but truth is more my friend." On the contrary, there is one passage in which Mr. Mivart almost seems to apologize for having, on some former occasion, spoken of Mr. Darwin with too much courtesy. For this he has now atoned to an extent almost ludicrous. We should not have felt in the least surprised had we found it proved—of course by strictly metaphysical arguments—that the author of the "Origin of Species" is the veritable transgressor who—

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[1] "Contributions to the Theory of Natural Selection," p. 13.

> "Filled the butchers' shops with large blue flies,"

or who—

> "With foul earthquakes ravaged the Caracas,
> And raised the price of sugars and tobaccos."

Suppose, in all sober sadness, an inquirer knowing nothing more of Darwin than what he might learn out of "Lessons from Nature." Would he not go away with the impression that our great English naturalist had done little beyond launching a "puerile hypothesis," and had played a very unimportant—and, if anything, rather injurious—part in the development of biological science? Yet every candid critic must admit that, were the theory of natural selection superseded to-morrow, to Darwin would still belong the merit of effecting in natural history a transformation as signal as that wrought in astronomy by Galileo, Copernicus, and Kepler, or in chemistry by Lavoisier; of bestowing upon zoölogy and botany a definite purpose and a direction for research such as before were wanting. His works would still remain a treasury of observations and of suggestions, and the impulse he has given to the science would never die away. In England, Germany, America, naturalists have sprung up as if by magic in obedience to his spell, and Mr. Mivart himself can hardly be excluded from their number.

We need scarcely add that a critic unjust to persons will not be much more trustworthy as regards their discoveries and their doctrines. The evidence in favor of natural selection—and indeed of evolution altogether—is strictly cumulative, and as such, whatever weight it may carry to the patient and dispassionate inquirer, it is peculiarly open to the attacks of an opponent at one skillful and unscrupulous. We do not, of course, mean to accuse Mr. Mivart of deliberate unscrupulousness. We all know the words—in themselves literally reeking with hypocrisy—in which "the Church" pronounced sentence of death on Giordano Bruno: "*Ut quam clementissime et citra sanguinis effusionem puniretur*" (Let him be punished as leniently as may be, and without shedding blood). Yet even on that occasion we should be reluctant to declare that the judges were sinning against better light and knowledge. Just so here: Mr. Mivart doubtless believes and feels what he says, and considers his own line of criticism fair and honorable. We know that man is an adept in self-delusion, and of all men the metaphysician who has cultivated the art *s'égarer avec méthode* (of going astray methodically) is most likely to go unconsciously astray.

We come now to a most painful subject, which, indeed, we would gladly pass over were not its consideration absolutely imperative. Mr. Mivart complains that in one particular instance Mr. Darwin departs from his ordinary courtesy to opponents. We are therefore justified in assuming that he regards courtesy to opponents as a duty —at least in others. Bearing in mind this circumstance, we turn to page 144, and read: "It is in one respect a calamity of our time and country that unbelievers, instead of, as in France, honestly avowing their sentiments, disguise them by studious reticence—as Mr. Darwin at first studiously disguised his views as to the bestiality (!) of man, and as the late Mr. Mill silently allowed himself to be represented to the public as a thorough believer in God." Along with this passage we take the remarks on "Mr. Winwood Reade, a friend and ardent disciple of Mr. Darwin," and on the teachings of "our English physical expositors" (pp. 393–395), and then ask whether the author is not, by implication at least, charging Mr. Darwin with atheism? This is the more probable, as we can find no saving clause or limitation guarding against such a construction being put upon these passages. Still, in a charge so grave the accused is entitled to the benefit of the faintest doubt, and Mr. Mivart may therefore claim a verdict of "Not proven." It is time, however, that we came to a full understanding about the foul practice of introducing charges of atheism in scientific controversy. On this subject we beg to offer the following considerations:

1. Charges of "heresy," "infidelity," or "atheism," are beside the question. If a theory in astronomy, in geology, in physics, chemistry, or biology, is in doubt, let it be judged on its own evidence; that is, let it be compared respectively with astronomical, geological, physical, chemical, or biological facts, and, according as it is able or unable to account for and to harmonize such, let it stand or fall. The man who is unable or unwilling to do this convicts himself, from an intellectual point of view, either of impotence or perversity, and should leave controversy to others.

2. Such charges, further, are delusive. Not to speak of the thoroughly-trained scholar, even many of the "half-educated" know that almost every important discovery in science has been denounced by the "*parti prêtre*" (clerical party) as impious, heretical, and atheistic. A yearly volume of the *Quarterly Journal of Science* would not contain the abuse uttered by ecclesiastics against the Copernican theory of the solar system, against the doctrine of a plurality of worlds, the Newtonian view of the universe, the nebular hypothesis, the chronology of modern geologists, etc. Yet all these views, and many more which might be mentioned, were found—when passion had cooled and sober judgment had time to decide—perfectly compatible, not with theism merely, but with Christian revelation. What "the Church" has cursed in one generation, she "assimilates" in the next. What educated man, then, after reviewing the past, can dare to set aside modern theories in such a manner?

3. Such charges are, further, distinctly immoral, and even criminal. All civilized countries brand with ignominy the suitor or the advocate who suborns false witnesses, forges or destroys documents, or corrupts judges and juries. But the controversialist who charges his opponent with atheism stands in a precisely similar position. He

well knows that, although the public might not admit, *totidem verbis* (in so many words), that "whatever an atheist advances must be false," or that "every theory once pronounced atheistic must be erroneous," yet it will practically act as if such propositions were established. Hence by making such charges he fraudulently attempts to steal from the public, through an appeal to their passions, a verdict which he has no hope of obtaining from their reason. Knowing and trading on the extreme animosity with which the heretic, the skeptic, and the atheist are—rightly or wrongly—regarded, he seeks to deprive his opponents of a fair hearing by applying to them these dreaded names. A meaner, a more infamous stratagem can scarcely be conceived. Yet more: it is not the man conscious of the goodness of his cause who fights with such weapons. He who knows that his views are in harmony with facts has nothing to gain by foul play; but if he feels inward misgivings concerning the doctrines which he advocates, or doubts at least the possibility of bringing forward valid arguments in their defense, he may readily, if dishonest enough, seek to blacken the character of an opponent.

We may, therefore, safely and fairly conclude that whosoever in scientific controversy introduces accusations of atheism is, if not knowingly and willfully, still decidedly in the wrong. We are consequently fully justified in shutting his book, and giving judgment against him.

But there is another consideration which here forces itself upon our attention. All writings calculated to bring a man into general "ridicule, hatred, or contempt," are by the law declared to be libelous. Now, it is very questionable if, in England, any accusation is so much calculated to bring a man into "hatred and contempt" as a charge of atheism or "materialism," however ill-founded it may be. Surely therefore such charges, whether brought directly or by implication, are libelous, and as such they are more fitted to be dealt with by a criminal court than by reviewers. We should like to see such a case decided, and we believe that the result would be a great improvement in the tone of scientific and semi-scientific controversy.

But even if such accusations should be pronounced not libelous, and if those who resort to them have no legal penalties to dread, there is another tribunal which might interfere. Why should not scientific men, scientific societies, and scientific journals, agree that whosoever in a scientific controversy attempts to get rid of an opponent by raising the cry of atheism should be held to be *ipso facto* an outlaw, and to be no longer entitled to the treatment of a gentleman and a scholar? Nay, why should not other charges affecting the personal character of an opponent be dealt with in a similar manner? We do not, of course, seek to screen the man who can be proved to have suppressed documents, cooked results, or claimed as his own discoveries those which he well knew belonged to another. We refer to those random charges of dishonesty and mendacity, and those sweeping ascriptions of motive which are unfortunately so common. Thus we have often heard and seen it asserted that the authors of some particular theory were actuated by a desire to disprove the existence of a God, to subvert the Christian religion or some particular form of it, or to injure public morals. To such assertors we would reply: "Prove your charge by evidence, such as would satisfy an impartial court of justice, or take the consequences, which will not be pleasant!" We are here reminded that in the very passage in Mr. Mivart's book (p. 144), in which he comes unpleasantly near charging Mr. Darwin with atheism, he brings forward against the same gentleman something very like an accusation of dishonesty. It is perfectly true that in the "Origin of Species" Mr. Darwin does not pronounce as to whether mankind had or had not been gradually evolved from some lower form of animal life. But reticence is very different from dishonesty. A thinker is not absolutely bound to bring his speculations to light at all; for keeping them back, while he is accumulating and weighing the evidence for and against them, he deserves praise rather than censure. Nay, even for introducing doctrines gradually, as the public are able to bear them, there is certainly authority which Mr. Mivart cannot consistently impugn. Nor must we forget that Mr. Darwin has, from the first, nowise courted publicity for his views. But for the fact that Mr. Wallace was known to be preparing a work of a somewhat similar nature, even the "Origin of Species" might never have seen the light.

There may be persons who will be aggrieved at this expression of our views on the subject of scientific controversies; but if they feel themselves guiltless they may cheerfully exclaim, "Let the galled jade wince." As for those who have actually made the kind of charges we protest against, they have no claim to lenity or forbearance.

Controversies on theories in the various inorganic sciences have been carried on with no little acrimony. But charges of atheism are, at least, banished. Why may not this reform be extended to biology and psychology? Those who cannot treat these subjects from a purely scientific point of view may serve to test the patience of unfortunate reviewers, but they cannot lead us to the truth.—*Extract from Article in the Quarterly Journal of Science.*

# LESSONS IN ELECTRICITY.[1]

## HOLIDAY LECTURES AT THE ROYAL INSTITUTION.

By Prof. TYNDALL, F. R. S.

### IV.

SECTION 17. *History of the Leyden-Jar.*—The next discovery which we have to master throws all former ones into the shade. It was first announced in a letter addressed on the 4th of November, 1745, to Dr. Lieberkühn, of Berlin, by Kleist, a clergyman of Cammin, in Pomerania. By means of a cork, *C*, Fig. 23, he fixed a nail, *N*, in a phial, *G*, into which he had poured a little mercury, spirits, or water, *W*. On electrifying the nail he was able to pass from one room into another with the phial in his hand and to ignite spirits of wine with it. "If," said he, "while it is electrifying I put my finger, or a piece of gold which I hold in my hand, to the nail, I receive a shock which stuns my arms and shoulders."

In the following year Cunæus, of Leyden, made substantially the same discovery. It caused great wonder and dread, which arose chiefly from the excited imagination. Musschenbroek felt the shock, and declared in a letter to a friend that he would not take a second one for the crown of France. Bleeding at the nose, ardent fever, a heaviness of head which endured for days, were all ascribed to the shock. Boze wished that he might die of it, so that he might enjoy the honour of having his death chronicled in the "Paris Academy of Sciences." Kleist missed the explanation of the phenomenon; while

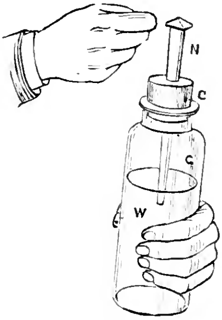

FIG. 23.

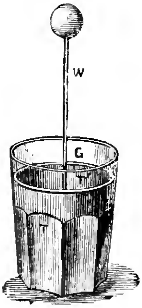

FIG. 24.

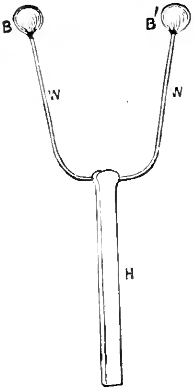

FIG. 25.

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[1] A course of six lectures, with simple experiments in frictional electricity, before juvenile audiences during the Christmas holidays.

the Leyden philosophers correctly stated the conditions necessary to the success of the experiment. Hence the phial received the name of the Leyden-phial, or Leyden-jar.

The discovery of Kleist and Cunæus excited the most profound interest, and the subject was explored in all directions. Wilson, in 1746, filled a phial partially with water, and plunged it into water, so as to bring the water surfaces, within and without, to the same level. On charging such a phial the strength of the shock was found greater than had been observed before.

Two years subsequently Dr. Watson and Dr. Bevis noticed how the charge grew stronger as the area of the conductor in contact with the outer surface increased. They substituted shot for water inside the jar, and obtained substantially the same effect. Dr. Bevis then coated a plate of glass on both sides with silver-foil, within about an inch of the edge, and obtained from it discharges as strong as those obtained from a phial containing half a pint of water. Finally, Dr. Watson coated his phial inside and out with silver-foil. By these steps the Leyden-jar reached the form which it possesses to-day.

It is easy to repeat the experiment of Dr. Bevis. Procure a glass plate nine inches square; cover it on both sides with tin-foil six inches square. Connect one side with the earth and the other with the machine. Charge and discharge: you obtain a brilliant spark.

In our experiment with the golden fish (Fig. 22), we employed a common form of the Leyden-jar, only with the difference that to get to a sufficient distance from the glass, so as to avoid the attraction of the fish by the jar itself, the knob was placed higher than usual. But, with a good flint-glass tumbler, a piece of tin-foil, and a bit of wire, you can make a jar for yourself. Bad glass, remember, is not rare. In Fig. 24 you have such a jar. *T* is the outer, *T′* the inner coating, reaching to within an inch of the edge of the tumbler *G*. *W* is the bit of wire fastened below by wax, and surmounted by a knob, which may be of metal, or of wax or wood, coated with tin-foil. In charging the jar you connect the outer coating with the earth—say with a gas-pipe or a water-pipe—and present the knob to the conductor of your machine. A few turns will charge the jar. It is discharged by laying one knob of a "discharger" against the outer coating, and causing the other knob to approach the knob of the jar. Before contact, the electricity flies from knob to knob in the form of a spark.

A "discharger" suited to our means and purposes is shown in Fig. 25. *H* is a stick of sealing-wax: *W′ W* a stout wire bent as in the figure, and ending in the knobs *B B′*. These may be of wax coated with tin-foil. Any other light conducting knobs would of course answer. The insulating handle *H* protects you effectually from the shock.

Sec. 18. *Explanation of the Leyden-Jar.*—The principles of electrical induction with which you are now so familiar will enable you to thoroughly analyze and understand the action of the Leyden-jar. In charging the jar, the outer coating is connected with the earth and the inner coating with the electrical machine. Let the machine, as usual, be of glass yielding positive electricity. When it is worked the electricity poured into the jar acts inductively across the glass upon the outer coating; attracting its negative and repelling its positive to the earth. Two mutually attractive electric layers are thus in presence of each other, being separated merely by the glass. When the machine is in good order and the glass of the jar is thin, the attraction may be rendered strong enough to perforate the jar.

Franklin saw and announced with clearness the escape of the electricity from the outer coating of the jar. His statement is that, whatever be the quantity of the "electric fire" thrown into the jar, an equal quantity was dislodged from the outside. We have now to prove by actual experiment that this explanation is correct.

Place your Leyden-jar upon a table, and connect the outer coating with your electroscope. There is no divergence of the leaves when electricity is poured into the jar.

But here the outer coating is connected through the table with the earth. Let us cut off this communication by an insulator. Place the jar upon a board supported by warm tumblers, or upon a piece of vulcanized India-rubber cloth, and again connect the outer coating with the electroscope. The moment electricity is communicated to the knob of the jar the leaves of Dutch metal diverge. Detach the wire by your discharger and test the quality of the electricity—it is positive, as theory declares it must be.

Consider now the experiment of Kleist and Cunæus (Fig. 23). You will, I doubt not, penetrate its meaning. You will see that in their case the *hand* formed the outer coating of the jar. When electricity was communicated through the nail to the water within, that electricity acted across the glass inductively upon the hand, attracting the one fluid and repelling the other to the earth.

Again I say, prove all things; and what is here affirmed may be proved by the following beautiful and conclusive experiment: Stand on your board, insulated by its four tumblers; or upon a sheet of gutta-percha, or vulcanized India-rubber. Seize the old Leyden-phial with your left hand, and touch the electroscope with the right, or with a lath or a wire held in the right. When electricity is communicated to the nail, the leaves immediately diverge by the electricity driven from your left hand through your body to the electroscope.

Here the nail may be electrified either by connecting it with the prime conductor of the machine, or by simply rubbing it with an excited glass rod. Indeed, I should prefer your resorting to the simplest and cheapest means in making these experiments.

As a thoughtful and reflective boy you cannot, I think, help wondering at the power which your thorough mastery of the principles of induction gives you over these wonderful and complicated phenomena. By those principles the various facts of our science are bound together to an organic whole. But we have not yet exhausted the fruitfulness of this principle.

Consider the following problem. Usually we allow the electricity of the outer coating to escape to the earth. Suppose we try to utilize it. Place, then, your jar upon vulcanized India-rubber, and connect its outer coating by a wire with the knob or inner coating of a second jar. What will occur when the first jar is charged? Why, the second one will be charged also by the electricity which has escaped from the outer coating of the first. And suppose you connect the outer coating of the second insulated jar with the inner coating of a third; what occurs? The third jar will obviously be charged with the electricity repelled from the outer coating of the second. Of course, we need not stop here. We may have a long series of insulated jars, the outer coating of each being connected with the inner coating of the next succeeding one. Connect the outer coating of the last jar with the earth, and charge the first jar. You charge thereby the entire series of jars. In this simple way you master practically, and grasp the theory of the celebrated "*cascade battery*" of Franklin, represented in Fig. 26, with coated glass tumblers, *A*, *B*, *C*, *D*, and so on. You must see that, before making the experiment, you could really have predicted what would occur. This power of prevision is one of the most striking characteristics of science.

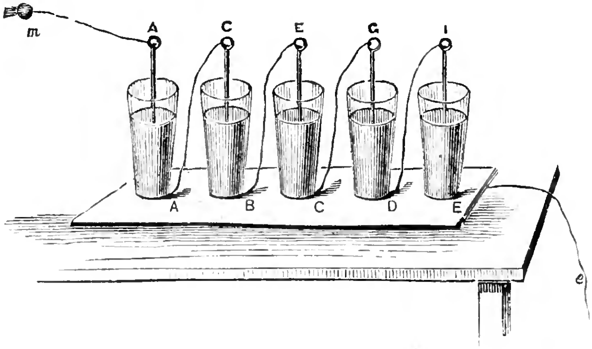

FIG. 26.

SEC. 19. *Novel Leyden-Jars of the Simplest Form.*—But, possessed of its principles, we can reduce the Leyden-jar to a far simpler form than any hitherto dealt with. Spread a sheet of tin-foil smoothly upon a table, and lay upon the foil a pane of glass, somewhat smaller than the foil in size. Remember that the glass, as usual, must be dry. Stick on to the glass by sealing-wax two loops of narrow silk ribbon, by which the pane may be lifted; and then lay smoothly upon the glass a second sheet of tin-foil, less than the pane in size.

Carry a fine wire from the upper sheet of tin-foil to your electroscope. A little weight will keep the end of the wire attached to the tin-foil.

Rub this weight with your excited glass tube, two or three times if necessary, until you see a slight divergence of the Dutch metal leaves. Or, connecting the weight with the conductor of your machine, turn very carefully until the slight divergence is observed. What is the condition of things here? You have poured, say, positive electricity on to the upper sheet of metal. It will act inductively across the glass upon the under sheet, the positive fluid of which will escape to the earth, leaving the negative behind. You see before your mind's eye two layers holding each other in bondage. Now, take hold of your loops and lift the glass plate, so as to separate the upper tin-foil from the lower. What would you expect to occur? Freed from the grasp of the lower layer, the electricity of the upper one will diffuse itself over the electroscope so promptly and powerfully that, if you are not careful, you will destroy the instrument by the mutual repulsion of its leaves.

Practise this experiment, which is perfectly easy and perfectly beautiful, by lowering and lifting the glass plate, and observing the corresponding rhythmic action of the leaves of the electroscope. The experiment was shown here twelve years ago to boys and girls who are now men and women.

Common tin-plate may be used in this experiment, instead of tin-foil, and a sheet of vulcanized India-rubber instead of the pane of glass. Or, simpler still, for the tin-foil a sheet of common unwarmed foolscap may be employed. Satisfy yourself of this. Spread a *sheet* of foolscap on a table; lay the plate of glass upon it, and spread a *leaf* of foolscap, less than it in size, on the plate of glass. Connect the leaf with the electroscope, and charge it exactly as you charged the tin-foil. On lifting the glass with its leaf of foolscap, the leaves of the electroscope instantly fly apart; on lowering the glass, they again fall together. Abandon the under sheet altogether, and make the table the outer coating; if it be not of very dry wood, or covered by an insulating varnish, you will obtain with it the results obtained with the tin-foil, tin, and foolscap.

The withdrawal of the electricity from the electroscope, by lowering the plate of glass, so as to bring the electricity of the upper coating within the grasp of the lower one, is sometimes called "condensation." The electricity on one plate or sheet was figured as squeezed together, or condensed, by the attraction of the other. A special instrument, called a *condenser*, is constructed by instrument-makers to illustrate the action here explained.

You may readily make a condenser for yourself. Take two circles, *P P′*, Fig. 27, of tin or of sheet-zinc, and support the one, *P′*, by a stick of sealing-wax or glass, *G*; the other, *P*, by a metal stem, connected with the earth. The insulated plate, *P′*, is called the collecting plate; the uninsulated one, *P*, the condensing plate. Connect the collecting plate with your electroscope by the wire, *W*, and bring the condensing plate near it, leaving, however, a thin space of air between them. Charge the collector, *P*, or the wire, *W*, with your glass rod, until the leaves of the electroscope *begin* to diverge. Withdraw the condensing plate, the leaves fly asunder; bring the condensing plate near, the leaves again collapse.

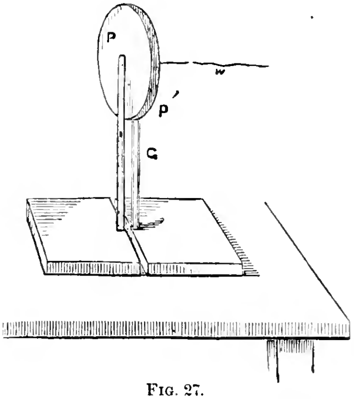

FIG. 27.

Or, vary your construction, and make your condenser thus: Employing the table, or a sheet of foolscap if the table be an insulator, as one plate of the condenser, spread upon it the sheet of India-rubber, *P*, Fig. 28, and lay upon the rubber the sheet of block-tin, *A*, *B*. Connect the tin by the wire, *W*, with the electroscope, *T R L*. Impart electricity to the little weight, *A*, till the leaves, *L*, begin to diverge; then lift the tin plate by its two silk loops; the leaves, *L*, at once fly asunder.

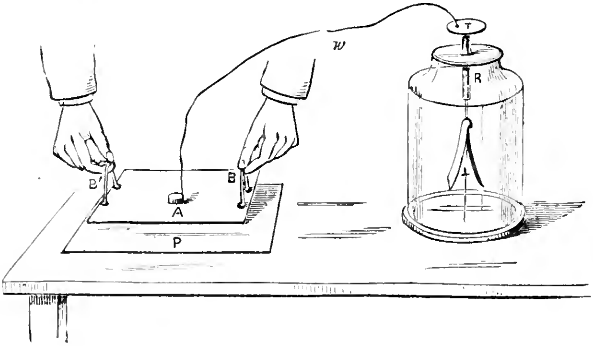

FIG. 28.

Finally, show your complete knowledge of the Leyden-jar, and your freedom from the routine of the instrument-makers, by making a "jar," in the following novel way: Stand upon a board supported by warm tumblers. Hold in your right hand a sheet of vulcanized India-rubber, and clasp, with it between you, the left hand of a friend. Place your left hand on the conductor of the machine, and let it be worked. You and your friend soon feel a crackling and a tickling of the hands, due to the heightening attraction of the opposite electricities across the India-rubber. The hand-jar is then charged. To discharge it you have only to bring your other hands together: the shock of the Leyden-jar is felt.

By the discharge of the hand-jar you can fire gunpowder. But this will be referred to more particularly further on.

Sec. 20. *Physiological Effects of the Shock.*—The physiological effect of the shock was variously studied. Graham caused a number of persons to lay hold of the same metal plate, which was connected with the outer coating of a charged Leyden-jar, and also to lay hold of a rod by which the jar was discharged. The shock divided itself equally among them.

The Abbé Nollet formed a line of one hundred and eighty guardsmen, and sent the discharge through them all. He also killed sparrows and fishes by the shock. The analogy of these effects with those produced by thunder and lightning could not escape attention, nor fail to stimulate inquiry.

Indeed, as experimental knowledge increased, men's thoughts became more definite and exact as regards the relation of electrical effects to thunder and lightning. The Abbé Nollet thus quaintly expresses himself: "If any one should take upon him to prove, from a well-connected comparison of phenomena, that thunder is, in the hands of Nature, what electricity is in ours, and that the wonders which we now exhibit at our pleasure are little imitations of those great effects which frighten us, I avow that this idea, if it was well supported, would give me a great deal of pleasure." He then points out the analogies between both, and continues thus: "All those points of analogy, which I have been some time meditating, begin to make me believe that one might, by taking electricity as the model, form to one's self, in relation to thunder and lightning, more perfect and more probable ideas than what have been offered hitherto.[1]"

These views were prevalent at this time, and out of them grew the experimental proof by the great physical philosopher, Franklin, of the substantial identity of the lightning-flash and the electric spark.

Franklin was twice struck senseless by the shock. He afterward sent the discharge of two large jars through six robust men; they fell to the ground and got up again without knowing what had happened; they neither heard nor felt the discharge. Priestley, who made many valuable contributions to electricity, received the charge of two jars, but did not find it painful.

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[1] Priestley's "History of Electricity," pp. 151, 152.

This experience agrees with mine. In the theatre of the Royal Institution, and in the presence of an audience, I once received the discharge of a battery of fifteen Leyden-jars. Unlike Franklin's six men, I did not fall, but, like them, I felt nothing. I was simply extinguished for a sensible interval.

This may be regarded as an experimental proof that people killed by lightning suffer no pain.

SEC. 21. *Seat of Charge in the Leyden-Jar.*—Franklin sought to determine how the charge was hidden in the Leyden-jar. He charged with electricity a bottle half-filled with water and coated on the outside with tin-foil; dipping the finger of one hand into the water, and touching the outside coating with the other, he received a shock. He was thus led to inquire, Is the electricity in the water? He poured the water into a second bottle, examined it, and found that it had carried no electricity along with it.

His conclusion was, that "the electric fire must either have been lost in the decanting or must have remained in the bottle. The latter he found to be true; for, filling the charged bottle with fresh water, he obtained the shock, and was, therefore, satisfied that the power of giving it resided in the glass itself."[1] An account of Franklin's discoveries was given by him in a series of letters addressed to Peter Collinson, Esq., F. R. S., from 1747 to 1754.

So much for history; but you are to verify the history by repeating Franklin's experiments. Place water in a wide glass vessel; place a second glass vessel within the first, and fill it to the same height with water. Connect the outer water by a wire with the earth, and the inner water by a wire with the electric machine. One or two turns furnish a sufficient charge. Removing the inner wire, and dipping one finger into the outside and the other into the inside water, a smart shock is felt. This was Franklin's first experiment.

Pass on to the second. Coat a glass jar with tin-foil (not too high); fill it to the same height with water, and place it on India-rubber cloth. Charge it by connecting the outside coating with the earth, and the water inside (by means of a stem cemented to the bottom of the jar and a knob) with an electric machine. You obtain a bright spark on discharging. This proves your apparatus to be in good order.

Recharge. Take hold of the charged jar with the India-rubber, and pour the water into a second similar jar. No sensible charge is imparted to the latter. Pour fresh unelectrified water into the first jar, and discharge it. The retention of the charge is shown by a brilliant spark. Be careful in these experiments, or you will fail, as I did at first. Note that the edge of the jar out of which the water is poured is to be surrounded by a band of bibulous paper to catch the final drop.

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[1] Priestley's "History of Electricity," third edition, p. 149.

These experiments are now made by rendering the coatings of the Leyden-jar movable. Such a jar may be charged, the interior coating may be lifted out and proved unelectric. The glass may then be removed from the outer coating and the latter proved unelectric. Restoring the jar and coatings, on connecting the two latter, the discharge passes in a brilliant spark.

Make a jar with movable coatings thus: Roll cartridge-paper round a good flint-glass tumbler, *G*, Fig. 29, to within about an inch of the top. Paste down the edge of the paper, and put a paper bottom to it corresponding to the bottom of the glass. Coat the paper, *T*, inside and out with tin-foil. Make a similar coating, *T'*, for the inside of the tumbler, attaching to it an upright wire, *W*, ending in a hook. You have then, to all intents and purposes, a Leyden-jar.

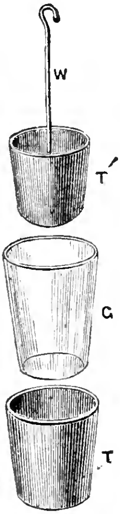

Fig. 29.

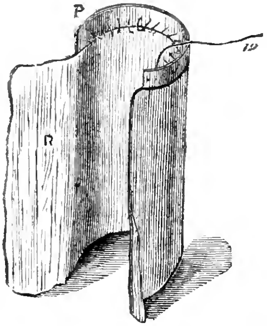

Fig. 30.

Charge the jar, and by means of a rod of glass, sealing-wax, or gutta-percha, lift out the interior coating. It will carry a little electricity away with it. Place it upon a table and discharge it wholly. Lift the glass by the hand out of the outer coating. Neither of the coatings now shows the slightest symptom of electricity. Restore the tumbler to its outer coating, and, by means of the hook and insulating rod, restore the inner coating to its place. Discharge the jar: you obtain a brilliant spark. The electricity which produces this spark must have been resident in and on the glass.

You can charge your jar with a rubbed glass rod, though a machine in good working order will do it more rapidly.

Sec. 22. *Ignition by the Electric Spark.*—Various attempts had been vainly made by Nollet and others to ignite inflammable substances by the electric spark. This was first effected by Ludolf, at the opening of the Academy of Sciences by Frederick the Great, at Berlin, on the 23d of January, 1744. With a spark from the sword of one of the court cavaliers present on the occasion, Ludolf ignited sulphuric ether.

Dr. Watson also made numerous experiments on the ignition of bodies by the electric spark. He fired gunpowder and discharged guns. Causing a spoon containing ether to be held by an electrified person, he ignited the ether by the finger of an unelectrified person. He also noticed that the spark varied in color when the substances between which it passed varied.

These, and numerous other experiments, may be made with a far simpler "machine" than any hitherto described. It was devised for your benefit by Mr. Cottrell. In the electric machine, as we have learned, the prime conductor is flooded with positive electricity through the discharge of the negative from the points against the excited glass. Your glass tube may be similarly turned to account. A strip of sheet-brass or copper, *P*, Fig. 30, about five inches long and one inch wide, is sewn on to the edge of the silk pad, *R*, employed as a rubber. Through apertures in the strip of metal about twenty pin-points are introduced and soldered to the metal. When the tube is clasped by the amalgam-covered rubber, the metal strip and points quite encircle the tube.

When a fine wire, *w*, connects the strip of metal with the knob of a Leyden-jar, by every downward stroke the glass tube is powerfully excited, and hotly following the exciting rubber is the circle of points. From these, against the rod, negative electricity is discharged, the free positive electricity escaping along the wire to the jar, which is rapidly charged.

Connecting the strip of metal with an insulated metallic knob, placed within a quarter or an eighth of an inch of an uninsulated argand burner, at every downward stroke of the rubber a stream of sparks passes between the knob and burner. If gas be turned on, it is immediately ignited by the stream of sparks. Blowing out the flame and repeating the experiment, a single stroke of the tube infallibly ignites the gas. Sulphuric ether, in a spoon which has been previously warmed, is thus ignited: but the ether soon cools by evaporation; its vapor is diminished, and it is then less easy to ignite. Bisulphide of carbon may be substituted for the ether, with the certainty that every stroke of the rubber will set it ablaze.[1] The spark thus obtained also fires an electric pistol charged with a mixture of oxygen and hydrogen. The two gases unite with explosion to form water, when an electric spark is passed through them.

Mr. Cottrell has mounted his glass tube so as to render friction in both directions available. The *tube-machine* is represented in Fig.

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[1] I am indebted to Dr. Debus for the suggestion of the bisulphide as a substitute for the ether.

31. *A B* is the glass tube, clasped by the rubber, *R*. *P P′* are strips of metal furnished with rows of points. From *P P′* wires proceed to the knob *C*, which is insulated by the horizontal stem, *G*, from the stand of the machine. This insulating stem may be abolished with advantage, the wires from *P* and *P′* being rendered strong enough to support the ball *C*. At *C* sparks may be taken, a Leyden-jar charged, the electric mill turned, while wires carried from it may be employed in experiments on ignition.

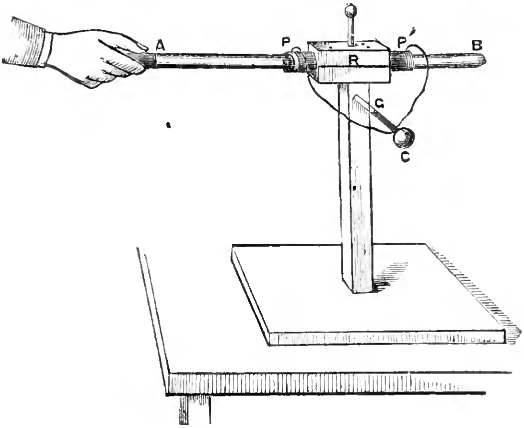

Fig. 31.

"Seldom," says Riess, "has an experiment done so much to develop the science to which it belongs as this of the ignition of bodies by the electric spark." It aroused universal interest: the experiment was repeated in all royal houses. Money was ready for the further prosecution of electrical research. The experiment afterward spread among the people. Klingensticrna astonished King Frederick of Sweden by igniting a spoon of alcohol with a piece of ice. Riess considers it probable that the general interest thus excited led to the discovery of the Leyden-jar, which was made soon afterward.

Cadogan Morgan, in 1785, sought to produce the electric spark in the interior of solid bodies. He inserted two wires into wood, and caused the spark to pass between them: the wood was illuminated with blood-red light, or with yellow light, according as the depth at which the spark was produced was greater or less. The spark of the Leyden-jar produced within an ivory ball, an orange, an apple, or under the thumb, illuminates these bodies throughout. A lemon is especially suited to this experiment, flashing forth at every spark as a spheroid of brilliant golden light. The manner in which the lemon is mounted is shown in Fig. 32. The spark occurs at *s*. A row of eggs is also brilliantly illuminated throughout at the passage of every spark from a Leyden-jar.

SEC. 23. *Duration of the Electric Spark.*—The duration of the electric spark is very brief: in a special case, Sir Charles Wheatstone found it to be $\frac{1}{24000}$th of a second. This, however, was the maximum duration. In other cases it was less than the millionth of a second.

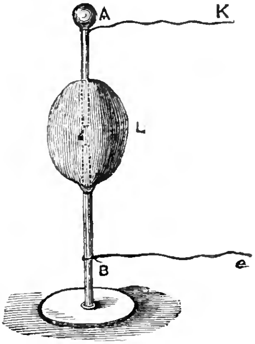

FIG. 32.

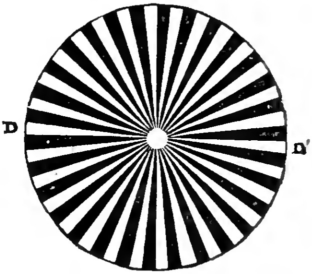

FIG. 33.

When a body is illuminated for an instant, the image of the body remains upon the retina of the eye for a fraction of a second. If, then, a body in swift motion be illuminated by an instantaneous flash, it will be seen to stand motionless for the fraction of a second at the point where the flash falls upon it. A rifle-bullet passing through the air, and illuminated by an electric flash, would be seen thus motionless; a circle like *D D'*, Fig. 33, divided into black and white sectors, and rotating so quickly as to cause the sectors to blend to a uniform gray, appears, when illuminated by the spark of a Leyden-jar, perfectly motionless, with all its sectors revealed. A falling jet of water, which appears continuous, is resolved by the electric flash into its constituent drops.

For a long time it was found almost impossible to ignite gunpowder by the electric spark, its duration was so brief; the powder, when the discharge occurred in its midst, was simply scattered violently about. In 1787 Wolff introduced into the circuit through which the discharge passed a glass tube wetted on the inside. He thereby rendered the ignition certain. This was owing to the retardation of the spark by the imperfect conductor. Gun-cotton, phosphorus, and amadou, which are torn asunder by the unretarded spark, are ignited when the discharge is retarded by a tube of water. A wetted string is the usual means resorted to for retardation when gunpowder is to be discharged.

The instrument usually employed for the ignition of powder is called a universal discharger. It is represented in Fig. 34. *I* and *I'* are insulating rods of glass or sealing-wax, supporting two metal arms, the ends of which can be brought down upon the little central table. Surrounding their ends with powder at *S*, and sending through the powder the unretarded charge, the powder is scattered mechanically. Introducing the wet string *w* into the circuit, it infallibly ignites.

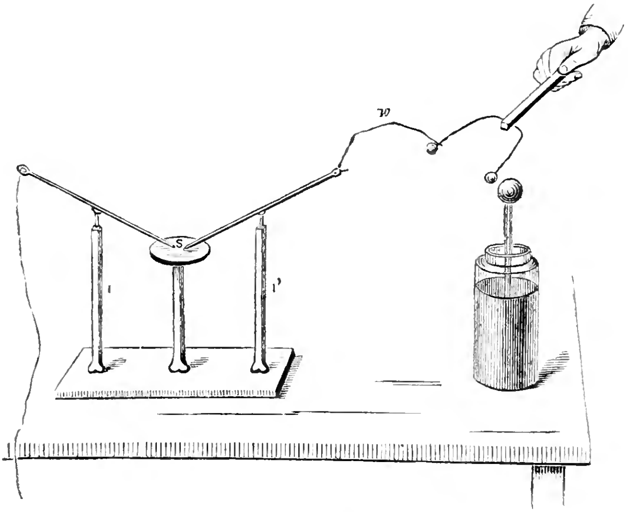

Fig. 34.

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# CERTAIN PHASES OF BIRD-LIFE.

By CHARLES C. ABBOTT, M. D.

NOTWITHSTANDING so general an interest has been taken in studying the habits of our birds, by both scientific and amateur naturalists, there are several phases of bird-life to which little or no attention has been paid; at least scant reference, if any, has been made to them, in ornithological literature.

One such feature of bird-life is the mode of acquiring the range of flight-power characteristic of each species. A careful and long-continued study of our birds in their chosen haunts, free from all unnatural (i. e., human) persecution, has enabled me to detect but little variation in the flight-powers of the individuals of any species of bird observed —far less than in the general range of their habits; but still, such individual variation, I think, does exist. A bird is not a perfectly-adapted machine, capable of faultlessly filling its destined place in Nature, and unerringly performing everything required of it. With the simple growth of the feathers of the wing, there does not come the ability to fly. Just as creeping precedes walking, in children, this is a gradually-acquired power. The commencement may be termed "flapping," and consists in simply breaking the force of a descent; this is followed by a more effectual use of the wings, and horizontal progression, and it is some time subsequent to this that the young birds attain to the power of *upward* flight. This holds good of a considerable number of species, studied with special reference to their flight, as the robin, the wood-thrush, cedar-bird, cat-bird, pewee, and indigo-bird.

It is doubtful if young birds, while yet in their nests, are conscious of the use to be made of their wings. After long-continued experimenting, I find they make no use of them, in endeavoring to escape, but trust to their legs entirely, if removed from the nest, or defend themselves by pecking at the intruder. When a sufficient growth of feather has been obtained, the parent-birds, directly and indirectly, instruct them; or, perhaps more properly, force them to use their wings. So, at least, I can only interpret certain habitual actions of the parent-birds with reference to their newly-fledged young.

As an instance I will quote from my field-notes, with reference to the indigo-bird: "June 23, 1873. Found a nest of this species in a dense thicket of blackberry, and, curiously enough, within just seven paces of the railroad-track. The young birds were just ready to leave the nest. I visited the nest the next day, and saw on my approach one of the four young birds sitting on a brier-stem, about a yard from the nest. Taking a favorable position, I continued to watch the birds closely, as they were very restless and noisy. Evidently something unusual had occurred or was occurring. In a few moments I saw the hen-bird go to the nest and push one of the young birds out of the nest. It forced it from the edge of the nest, to which it clung with its feet. Once free, the little fellow struggled to keep itself up, throwing *up* its wings, as a child would straighten out its arms when falling. This was the initial movement that developed into flight. All of the young birds were thus forced from the nest, and I am satisfied from no outside cause, as, for the three following evenings, the young returned to the nest to roost. I spent several hours watching this brood and their parents, and the whole time was occupied, except short intervals when they were fed, in forcing the young birds from point to point, but ever keeping them from the railroad-track, over which trains passed frequently. Two days from leaving the nest they could fly six or eight yards, but always from a higher to a lower perch, and regained the more elevated branches by very short, 'jumping' flights, with a laborious flapping of the wings; but on the fifth day they could follow their parents almost any distance, and execute an upward flight with apparently the same ease. Examination of the wing-feathers on the 30th of June, as compared with a week previous, showed so slight gain in the growth of the feathers, that I believe nothing in the increased flight-power was due to their being now better fledged."

Such observations as the one noted in detail I have so frequently repeated with widely-differing species as to satisfy me that what may be termed "direct instruction" in flight is given to the young birds by their parents. "Indirect instruction" also is noticeable, in the fact that the parent-birds cease to feed their young, and so force the latter to leave the nest and follow them. Once out of the nest, they soon endeavor to walk on air, as it were, and, falling, open their wings, and, as described, thus take the initial step. This ceasing to bring the food to the young while yet in the nest is done in some instances, I judge, only to draw them from the nest; and then they feed them as before, but not as frequently, which leads the young to voluntarily move from point to point. The important fact must not be lost sight of, too, that the young birds, when once out of the nest, witness nearly every movement of their parents, and learn, undoubtedly, very much through imitation of their movements.

For these reasons, I believe the acquisition of full flight-power is gradually acquired; first there is a mere "flapping" to prevent falling; then short horizontal stages of aërial progression; finally, a steady, intelligent use of the wings, enabling the birds to execute the highest type of flight within their capabilities, i. e., upward flight.

In the case of birds of more complicated flight than those mentioned above, such as the falcons, where hovering is a necessary acquirement, the truth of the assertion that flight is gradually acquired becomes more evident from the fact (which I have very frequently verified by observation) that the young birds for some time after leaving the nest are fed by their parents. They commence procuring food for themselves by chasing sparrows; checking their moderate flight when above a thicket, they rush upon the fleeing birds, more frequently without success than with. Their first attempts at hovering are miserable failures, and it is not until autumn that they are enabled, by the complete control of their wings, to stay themselves in mid-air, and, at the proper moment, dart with unerring aim upon some luckless mouse.

I have used the term "unerring," because it is customary so to characterize this act of the falcons; but, having watched, with a powerful field-glass, the hovering and darting of hawks, I have been forced to consider the term far from correct, and that not more than one-half, if as many, of the "strikes," on the part of the bird, are effectual.

Following the young birds, of any species, from the nests, and noting their movements, we find that the one prominent aim of their lives, during their first summer, is the acquisition of food. They have really nothing else to do, if we except escaping from the attacks of their enemies, and this is taught them directly by their parents. I judge that the great majority of birds that fall victims to birds of prey and carnivorous mammals are young. To return to the feeding-habits of birds. These appear to be acquired, by every bird, through imitation of the movements of the parents when in search of food; judgment as to localities, on the part of the young, and allied circumstances connected with procuring food, come by experience. Watch a restless little creeper, during these chill winter mornings (*Certhia familiaris*), as it flies from tree to tree, and clambers over and about the rough bark. It seems, indeed, a mere automaton, driven, and not going of its own free-will; but, if we continue our observations but a little longer, we shall find it really a discriminating creature, passing by certain trees that are to us all one with those visited. It is not chance, but a consciousness of the uselessness of search, that determines its flight to some more distant rather than a nearer tree.

As an example of the knowledge gained by young birds through imitation, let us take young woodpeckers. On leaving the nest, they accompany their parents, but are not fed by them. Like the old birds, they immediately commence to climb the trunks and branches of the trees. Having been fed with insects when in the nest, they are already able to recognize their proper food, and devour the visible insects they may discover on the outer surface of the bark. Now, was it the example set by their parents, or the peculiar construction of their bill and feet, that was the cause of their having sought the trees, and climbed over them in the peculiar manner common to their kind? I think, clearly the former. Now, merely clambering over the bark of trees would not enable them to secure sufficient food, and imitation could not extend beyond this point; but here experience comes into play, and the gradual acquirement of the whole routine is easily traced. The bark of trees is nearly always cracked, and in the crevices are more insects than on the surface, and the habit, soon acquired, of search in the cracks of the bark is the one step from searching over the exposed surface to search beneath. Imitation led the *ignorant* young bird to the thrifty growth of timber, and not the tangled hedge-rows. Experience taught him the accustomed haunts of those insects on which Nature bids him prey. If we go back into the remote past, and recall the ancestral woodpecker, we can with no undue use of the imagination picture to ourselves the first steps that led the good climber to find in the half-decayed bark the nourishing food abounding there; and now let us return to the present, and seek for some variation in the habits of the birds of to-day. As an instance, the "flicker," or golden-winged woodpecker, leaves the timber-lands, and in loose flocks, often in company with robins, wanders over pasture-fields and meadows in search of food, more especially the crickets, and not under fences do they look for them, but under the dry droppings of the cattle. Here is an instance where accident, it may be, gave origin to, and experience has confirmed into a habit, a decided variation from normal woodpecker life. Now, a young woodpecker leaving its nest June 1st, if dissociated from its kind, would never leave the woodlands, and, seeking the pasture-fields, overturn dry chips of cow-dung, in search of crickets; but such young birds will naturally follow their parents thither, and this is just the case, for the larger proportion of birds killed in October, in such localities, are the young of the preceding summer.

In conclusion, with reference to young birds, I believe they leave their nests *totally ignorant*, and *naturally* imitate their parents. What this imitation secures to them, in the way of knowledge, they perfect by experience; and this explains the variation in the habits of the same birds, so noticeable when studied in localities widely distant and greatly differing in character.

Let us turn our attention now to adult birds; and, with reference to them, I would refer particularly to two phases of their life-habits that have interested me exceedingly. The first of these points is the ingenuity so frequently displayed in procuring food. By the exercise of ingenuity, I mean instances of the attacking bird (in cases of birds of prey) being at first outwitted by the pursued, and, after repeated efforts availing nothing, ceasing its aggressive movements; then considering the causes of failure, planning a new method of action, and, having correctly judged the difficulties, finally succeeding. This, at least, is the manner in which I interpret the following instance:

While out watching our winter birds, January 22d of this year, I was caught in quite a hard shower, and sought shelter under a group of three large, dense cedars. Like myself, driven in from the adjoining meadows by the increasing rain, came a dozen or more sparrows, which, settling among the branches, commenced dressing their feathers and twittering cheerily. In a few moments after came, with a rush and loud chirp, a gay cardinal. If the sparrows did not acknowledge his presence with a low bow, each, at any rate, took a lower branch, leaving him on his elevated perch like a monarch on his throne. But he was fated to be molested, for, scarcely had he become fairly settled, and his feathers smoothed, when a sparrow-hawk rushed through the tree, with a zigzag movement, endeavoring to seize him or one of his attendant sparrows. Failing in this, the hawk hovered about a few moments, giving the scattered birds time to return, which they quickly did, when, with a similar rush, he again scattered them. One little snow-bird was so thoroughly frightened that it lit upon my shoulder, as though seeking safety under the brim of my hat. The third effort of the hawk failing, he came back immediately and seated himself at a little distance from the top of the tree, and close to the main stem. I remained nearly motionless, but with upturned face, and could plainly see the bird, although fortunately I escaped notice. One thing in particular attracted my notice: the bird was very much exhausted, "out of breath," as we should say of ourselves, and, with his beak open, he panted violently. This satisfied me that the efforts to capture prey are not accomplished with the ease sometimes supposed. As the rain was increasing, and the wind considerable, the sparrows again collected in the tree; and now the hawk rushed *out* instead of in, and bore a luckless sparrow in his claws.

I think that we have here all that I claimed, when speaking of ingenuity on the part of adult birds in seeking their food. There was in the above instance a painful consciousness, at first, of failure to secure the desired prey; there was a determination to succeed, in spite of failure at the start, and a correct determination of the cause of failure, coupled with the invention of a plan by which the difficulties might be overcome. What more should be required to demonstrate that the mental powers of lower animals differ from those of man solely in degree?

Again, let us consider a case of ingenuity displayed by a bird in successfully avoiding an enemy. Here there is more cause to be surprised at the result, inasmuch as there was no cessation of the attack, to give the pursued bird time for considering how best to act under the circumstances; but, while fleeing for life, it matured a plan of escape that happily succeeded. This instance of ingenuity on the part of a pursued bird I have already related (*Land and Water*, March 2, 1872), but, considering it more remarkable than any other that has occurred to my knowledge, and having witnessed a repetition of it, two years later, I again relate it, in preference to other instances I have noted, bearing upon the same subject. The case is that of a "king-rail" (*Rallus elegans*), which my spaniel flushed in open ground, the grass not being tall enough to conceal it. The bird trusted wholly to running, and kept clear of the dog; frequently it "doubled," and seemed to enjoy the chase; but, evidently becoming somewhat fatigued, as shown by the nearer approach of the spaniel, it ceased doubling, but, running in a straight line some distance, it allowed the dog to get within a foot or more, when it jumped, with a single flap of its wings, a foot or more from the ground; then dropping down quickly behind the dog, it turned and ran in the opposite direction, gaining considerable ground before the impetuous spaniel could check its speed, turn about, and follow. Here, again, as we would express it, in describing any human experience, "the circumstances of the case were taken into consideration" by the pursued bird, and, without taking to flight, as would seem the more natural act, it surmounted the difficulties, and effected its escape. I can conceive of no other way of explaining this action of the rail-bird, than by admitting that a train of thought passed through the brain of the bird—that it thought, "If I can gain time, I am safe," just as any pursued person would think that, if he could reach some spot, be heard, etc., he would be safe. And, while yet running at great speed, the bird *thought* of an ingenious plan, by which it *did* gain time, and reached the reedy creek-bank in safety

It might be argued that a single act of a bird, at some one time, and under peculiar circumstances, does not constitute a habit—that it simply chanced to do so and so; but a second occurrence of the kind would result differently. It must be remembered, however, that where a bird is noticed in its natural haunts, once, even if for more than an hour—which is an unusually long observation—there are weeks when this same bird is unseen, and therefore what its acts may be are absolutely unknown. For this reason, an ingenious act of a bird may be frequently repeated, and almost certainly is. Indeed, our ignorance of bird-life is so great, that what seem to us "curious instances," because but seldom witnessed, are frequently daily occurrences, and ordinary features of the bird's life. It can scarcely have escaped the notice of close observers of our winter birds, that their comparative abundance is only during clear, pleasant weather, when they will be as lively and restless as spring birds in early summer, and that during the winter certain localities, as the southern outlooks of wooded hillsides and such sheltered spots, are those where these hardy species "most do congregate." During a mild day, at some such spot, we can almost delude ourselves into thinking that spring is coming; but on the morrow a fierce wind rattles the bare branches above you, clouds of stinging dust, or driving snow, fill the chilled air, and not a bird is to be seen or heard, the cheery sights and sounds of yesterday having given place to a dreariness most drear. One question now arises, and we naturally ask, "What has become of the birds, so lately here?"

During the winter of 1874–'75 (the coldest except one—1835–'36—since 1780), I endeavored to determine to what extent these birds sought shelter, and the character of it, not only as a protection against severe storms, but as regular winter quarters, i. e., for roosting-places. I was led to do this from the fact that these winter residents, as the bluebird, the cardinal redbird, and the titmouse, do not roost in the trees, as in summer, and it seemed probable that, seeking warmer quarters in ordinary weather, they should seek shelter from severe storms, and not temporarily migrate to some point beyond the limits of the storm; not only this, but that some spot is selected early in the season as such roosting-place and refuge, and occupied as such throughout the season. So far as my observations extend, I was correct in my surmises.

I have, on my farm, a deep "gully," or ravine, thickly wooded, and with overhanging banks, extending a considerable portion of the entire length. This overhanging earth is held in place, partly by the character of the soil, and more by the roots of the trees growing near the margins of the gully. In this locality, under the overhanging earth, in some instances at a distance of three feet from the open ground, I found the snow-birds, song and chipping sparrows, occasionally a flock of cedar-birds, the arctic snow-bird, and horned larks, roosting; and, judging from the amount of excreta upon the ground, this had been the accustomed roosting-place for many weeks. A little before sundown, during January, I would find these birds, some or all of them, congregating in the adjoining fields and in the trees of the gully, and quite suddenly they would all disappear. Searching every possible hiding-place, I finally found them as above described. If the following day proved very cold or stormy, many of them would remain in their snug retreat, the arctic visitors being the first to venture out. The birds just mentioned all build open nests, either in trees or upon the ground. On the other hand, the titmouse, nuthatch, brown tree-creeper, and bluebird, all of which build nests in hollow trees, or sheltered spots of that character, I found regularly roosted in the hollow trees, or in the outbuildings of the farm. The cardinal redbirds, however, which nest in trees and brier-patches, usually took refuge in dense cedars, to roost, but sought other shelter during severe storms. For instance, during the remarkable wind-storm of February 9th, when the air was filled with dust, and the thermometer ranged from 3° to 4½° Fahr., no ordinary shelter could protect our resident birds. During the day not one was to be seen flying. I found the cardinal redbirds—a pair of them—had taken shelter in a large, hollow tree, and with them was quite a large number of titmice, a brown tree-creeper (*Certhia familiaris*), and several sparrows. I do not doubt but that the earth-shelter already described had proved inadequate, and that the birds usually roosting there had sought more sheltered spots. However, I did not have the courage to face the wind, and see for myself, if such was the case.

During the present winter I have found that some, at least, of our winter birds utilize the very excellent shelter afforded by the nests of our bank-swallows. February 20th, a bright, clear day, I passed by a high, steep cliff of compact sand and clay, much frequented by these swallows during summer. I noticed there chipping-sparrows and a bluebird sunning themselves, each at the opening of a nest. On driving them away I found that they circled about for a few moments, and returned. On passing the cliff again, some hours later, I saw these birds, and several others, some at the openings of the nests, and others flitting about, quite in the manner of swallows. I could not reach the nests, to determine if they had been much occupied during the winter, but do not doubt but that such was the case.

I have not found, however, any shelters constructed by birds for such purpose solely, except in the case of the introduced English sparrow, which builds quite an elaborate and very warm roosting-nest. During the early frosts of autumn and prevalence of cold rain-storms, occurring before the ordinary date of migratorial departure, the nests used in spring and summer are, I know, used as roosting-places, but I have not detected any refitting of them for this purpose. Considering this, it would be natural for birds to build new structures for winter use, and in the sparrow we have an instance of it, and, I presume, the abundance of natural shelter has alone prevented the gradual acquirement of this habit by our winter birds.

Having familiarized one's self with the various phases of bird-life, as it occurs in the open fields, dense thickets, along secluded streams, and in shady forests, one can scarcely conclude otherwise, if happily he has not entered upon his studies with some preconceived notion, than that these wild and wary falcons, timid sparrows, fiery little wrens, and cautious waterfowl, are creatures that, like man himself, are thrown upon the world dependent upon their own exertions, guided by their own reasoning powers. There are no prearranged rules which, when birds leave their nests, they must strictly follow, to exist. Given that knowledge which comes through direct and indirect instruction from the parent-birds, and a young bird, having the world before it, exercises just those mental powers that man exercises, but limited just so far as its own wants are less than man's wants as man. Finally, in the chance occurrence of some peculiar habit have we not a trace of the former mode of life of some far-distant ancestral form; and, in the undeniable irregularity of all habits, can we not discern unmistakable indications of the gradual adoption of every habit, just as the various specific forms themselves gradually emerged from the archaic creature that, appearing in the dim past, foreshadowed the gigantic condor of the Andes, and the petulant humming-birds of our summer gardens?

# "OF THE UNCERTAINTY AND VANITY OF THE SCIENCES."

By IRWIN RUSSELL.

ABOUT three hundred and fifty years ago, Henry Cornelius Agrippa wrote a very curious book, "De Incertitudine et Vanitate Scientiarum" (Of the Uncertainty and Vanity of the Sciences). Few people read it now. Yet it has its interest, as an exponent of the state of science at that day, aside from the attractions which are given it by the quaint, sarcastic style of the author.

Here it is, a very old edition, in the black-letter of the sixteenth century. The text has numerous peculiarities. The letter "ā," with a dash over it, represents "an;" there are two kinds of "r's;" the double "e's" and double "o's," respectively, are put on a single type. The emphasized words are printed in Roman characters, whereof the font contains no "w," and that letter is made by placing two "v's" together. The book is numbered by folios, instead of pages. The printer tells us that his edition is translated from the original Latin, compared with an Italian version. Let us transcribe some of Agrippa's remarks—altering the spelling to suit our modern rules.

Above all sciences, he favors geometry: "In fine, all the cunning that is in Painting, in the Measuring the world, in ground tilth and trimming, in the Art of war, in founding of metals, in the art of working Images in earth, in Image-making, in forging, in building and in metals, for the most part, cometh from geometry." He says, however, of the geometricians: "Yet such is their ambition, that they will never rest upon the precepts of their preceptors; but believing in such things to find out more than their Masters, do bring themselves into so great madness that all the Helleborus in the world sufficeth not to purge it." He instances as the fruits of this science, "all the cunning working of tools and artificial instruments, *Magnaries*, *Machanopocetickes*, *Poliorcetickes*, . . . . *Testudines*, *Cuniculines*, . . . . *Exosters*, *Sambukes*." Between paragraphs, the reader can consult the dictionary or encyclopædia.

We are told in cap. 23, "Of the Arte Opticke," that "there are sundry and divers opinions of the manner of seeing. For Plato supposeth the sight to be made according to the clearness: to wit, that which cometh from the eyes: the Light running to an outward air, that Light which is carried from the bodies being brought against it; but that which is about the midst of the air, doth cause that it spreadeth, and turneth back to the virtue of the Sight, being spread abroad, and like unto Fire. Galene and Plato are of one opinion; but Hipparchus saith, that the beams spreading abroad from the eyes unto bodies, touching them as it were with a certain feeling, or groping, do give that which they receive to the Sight. And the Epicures affirm that the similitudes of things not corporal, but according to the quality through the alteration of the air, which is in compass, doth come from visible things unto the sight. But Porphirius saith that, neither the Beams, neither the similitudes, nor any other thing, is the cause of seeing, but the soul alone, that knoweth herself visible, and that is one of all things, which knoweth herself in all things that are. The geometricians and perspectivians, approaching somewhat near to Hipparchus, do affirm that there be certain Figures made of the meeting together of the beams, which are sent out through the eyes, from whence the sight doth comprehend in one, many visible things, but they most certain of all, wheresoever the beams shall meet together. Certes, Alchindus saith otherwise of the Sights: but it seemeth to Augustine that the power of the Soul doth bring somewhat to effect in the eyes, the which is not yet perceived of the Students of Wisdom."

Although we have advanced much since the time of Cornelius Agrippa, still, even in this glorious nineteenth century there is here and there a thing "the whiche is not yet perceyved of the Studentes of Wisedome."

The following is a good example of our author's peculiar style: "Notwithstanding, I learned in time past in Italy, that there was in pictures and images an authority greatly to be esteemed; for whereas there was an obstinate strife between the Augustine Friars and the vulgar Canons, before the pope, concerning the habit or apparel of S. Augustine, that is to say, whether he did wear a black weed upon a white Coat, or a white weed upon a black Coat; and finding nothing in the Scriptures which made to the ending of this strife, the Roman judges thought good to prefer the whole matter to Painters and Image-makers, and that which they could avouch out of ancient Pictures and Images should be holden for a Definitive sentence. I being grounded upon this example, when some time I with exceeding great diligence searched for the Original of the Friars' cowl, and could find nothing for that matter in the Scriptures, at length I went me to the Painters, and for this thing I sought in the Cloisters, and in the cells of the Friars, where for the most part the histories of both Testaments are painted; and when I could not find in all the Old Testament none of the Patriarchs, none of the Priests, none of the Prophets, none of the Levites, nor yet Helias himself, whom the Carmelitans would have to be their Patron, with a cowl: taking the New Testament in hand, I found there Zacharie, Symeon, John Baptist, Joseph, Christe, the Apostles, the Disciples, the Scribes, the Pharisees, the High Priest Annas, Caiphes, Herode, Pilate, and many other, I saw in no place a Friar's cowl: and again diligently examining everything from the beginning, immediately in the fore part of the History the Devil was painted with a Cowl, to wit, he which went to tempt Christ in the Desert. I rejoiced exceedingly that I had found that in the pictures which until that time I could not see in writing, that is to say, that the Devil was the first author of a cowl: of whom afterwards, I suppose, that other Monks and Friars took up the fashion under divers colors; or, perhaps, have retained it as a thing left to them by inheritance."

Such passages as the last, which abound in the book, were not calculated to win for the writer the affection of the clergy. Through their influence, Agrippa was imprisoned for some time, and his pension from the Emperor of Austria was withdrawn.

"Seeing glasses" he classifies as follows: "The hollow, the embossed, the plain, the *Columnarie*, the *Piromidal*, the *Turbinal*, the bunched, the round, the cornered, the inversed, the eversed, the regular, the unregular, the massy, and the clear." He describes their properties, and says: "And I know how to make Glasses, in which, when the sun shineth, all things that are lightened of his beams may very plainly be seen a great space off, as three or four miles." Were these "glasses" on the principle of the telescope? The invention of that instrument is generally assigned to Galileo, about 1590; whereas Agrippa's book was published at Antwerp in 1530.

Astronomy he pronounces "altogether false, and fuller of trifling toys than the fables of the Poets"—declaring that the laws of the science, as then asserted, were only a mass of idle conjectures.

Of magic he says: "The things which the deluded and bewitched persons do imagine, have no truth of action and being, save only things imagined. For the end of this skill is not to do, simply, but to stretch out Imaginations even unto appearance."

The chapter on alchemy is a curiosity. One passage reads: "Finally, of that only blessed thing alone, besides which there is no other thing, yet to be found in every place, the subject of the most holy stone of the Philosophers, I mean, that is to say, I have almost rashly uttered the name of the thing, whereby I should be a sacrilege and forsworn, yet I will speak it with circumlocution, but somewhat more obscure, that none but young beginners in the Art and they which be trained up in the mysteries thereof may understand it. It is a thing, which hath substance, and not overmuch fiery, nor altogether earthly, nor simply watery, nor a most sharp nor most blunt quality, but indifferent, and light in touching, and after a sort tender, or at the least not hard, not unpleasant, but after a sort sweet in taste, sweet in smell, delectable to the sight, pleasant and jocund to the hearing, large to the imagination: I may say no more, and yet there be things greater than these." The description is scarcely definite enough to enable us to find the philosopher's stone.

The 102d chapter is "A Digression in prayse of the Asse"—after which follows the conclusion of the work, in which he salutes his readers, "O ye asses." Perhaps some modern authors would like to follow his example in this respect.

The printer, in his preface to this edition, remarks: "Sapience proceedeth of perfect Reason, joyned vvith Learning, and knovvledge, which if it be true, then consequently it follovveth, that Artes and Sciences are good. And although this Authour sharply inveyeth against them, (vvhich to the rude multitude for that cause may seeme naught and noysome) yet his intent is not to deface the vvorthiness of Artes and Sciences, but to reprove and detect their euill vses, and declare the excellencie of his vvit in disprouing them, for a shevve of learning."

Henry Cornelius Agrippa was one of the most learned men of his time, and wrote voluminously upon scientific and philosophical subjects. The "Edinburgh Encyclopædia" says of him: "As a soldier and a physician, a lawyer and a lecturer, a metaphysician and a theologian, the versatility of his genius enabled him to attain the highest distinction." He wrote a "Dissertation on Original Sin," a work on "Occult Philosophy," a "History of the Government of Charles V.," and various other treatises. The book from which we have quoted so largely is undoubtedly the most complete summary of the condition of science at that day to be found in any one volume.

Is it probable that our present accepted theories will seem as curious to the reader of three hundred and fifty years hence as those of Agrippa's day appear to us? Will the customs, the manners, and the laws of the world improve as rapidly in the future as they have in the past? If so, who would not wish to fall into such a trance as that of the Seven Sleepers—and wake, to find the rest of life all too short to enjoy the stupendous novelty?

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# ANIMAL POWERS OF OFFENSE AND DEFENSE.

THERE can hardly be any greater diversity observed in the animal series than that exemplified in the various means whereby animals are enabled to assume an offensive or defensive aspect. From the lowest to the highest grades of animal life—excepting, perhaps, man himself—we find ample provision made for the exigencies of animal existence, in so far as these exigencies demand the use of apparatus which gives its possessors some advantage or other in the "struggle for existence." Undoubtedly, in his superior intellectual organization, which enables man even in his rudest state to avail himself of almost every feature in his surroundings for advantage and defense, the human subject has been endowed above all other forms; and he therefore compensates himself by varied arts and stratagems for the want of the more rigid and natural appliances of lower forms. But if it be true that art is most to be admired when it closely imitates Nature, then the policy of man in his imitation, conscious or unconscious, of the many offensive arts of his humbler neighbors, must claim from us a fair share of favorable criticism.

Thus, it is a striking fact that very many human means of defense or offense find their prototypes, or at least strangely analogous features, in the extensive armory of the animal world at large. The lasso may be found in the apparatus whereby such a simple form as the *Hydra*, that tiny fresh-water polyp, secures its prey. Or, when human sharp-shooters think to conceal their whereabouts most effectually from the foes they purpose to annoy, and clothe themselves in garments of neutral tint, the hue of which shall most nearly resemble that of the objects amid which they are located, this principle of imitation of natural objects again finds a strict parallelism in the animal world. For it is a familiar fact to all observers of Nature that the color of most animals resembles more or less that of their natural surroundings. The color of the sand-grouse, for instance, and other species of grouse, of partridges and other birds inhabiting heaths, or of flounders and other fishes inhabiting the sand, strictly approximates in character to that of their dwelling-places, and serves to conceal and protect such beings. And, when we further discover that, in not a few cases, this principle of similarity to their surroundings is carried in some animals—such as the leaf-insects and walking-stick insects—to the extent of close and actual *mimicry*, our surprise is increased.

Or, lastly, when we find, as in the latest phase of modern warfare, that the concealed torpedo is used as a subtile and powerful means for effecting the destruction of whole fleets, the fact cannot but call to mind the electrical apparatus of some fishes—and notably that of the torpedo or electric ray—which exists as a natural means of defense, the powers of which, few, if any, of their less favored neighbors care to test or provoke.

While the consideration of the more prominent and typical means of defense in animals may very reasonably occupy our brief attention, a few words on the subject of mimicry in the animal series may also prove interesting, more especially as this form of protection, through imitation of their surroundings, forms a simple yet effective means of defense to many organisms. We have already referred to the readily-perceived and very general correspondence in color seen throughout the animal world between animals and their abodes; and of the more general aspects of this condition nothing further need be said. The more special and striking developments of mimetic resemblances are found in cases in which not merely the general color of their environments is imitated, but where resemblances of a close, and sometimes of a very extraordinary kind, to other animals, to plants, or even to inorganic objects, are to be noted. In the leaf-insects, which are included in the same order as locusts, crickets, etc., for example, the wings are not only colored to resemble leaves, but their structure imitates in the most exact manner the appearance of the veins of the leaf. Nor does the principle of imitation end with this sufficiently remarkable effect. In some leaf-insects the colors of the leaf-like wings actually change with the season of the year; as if in the most perfect sympathy and harmony with the alteration of colors in the actual leaves. And the mimicry becomes of still more perfect kind, to our thinking, when we find that the wings of the leaf-insect exhibit even the characteristic markings we are familiar with in leaves as produced by the attacks of minute insects; Nature thus imitating, not merely the natural structure of the leaf, but the very imperfections to which the leaf is subject. It has been suggested that the little leaf-eating insects may be themselves deceived by the mimicry of their larger neighbors, and may actually eat into the wings of the latter, and thus produce the eroded appearance. But, if this latter view be correct, it only makes out a stronger case for the perfect reproduction of the leaves in the wings of the insect. Mr. Wallace has given us a very typical example of another such case of the imitation, not only of leaves, but of the natural parasites of leaves, in a butterfly, the wings of which, on their under-surfaces, resemble leaves; while the imitations of decay of leaves and of the fungi that appear thereon are so close that, as Mr. Wallace remarks, "it is impossible to avoid thinking at first sight that the butterflies themselves have been attacked by real fungi."

The walking-stick insects, as they are called, in their turn imitate, in the skeleton-like structure of their bodies, the appearance of dried twigs; and it is a singular fact that even in their awkward, ungainly manner of walking, the resemblance to the chance movements of twigs is clearly perceptible; the mimicry being rendered more realistic through this latter phase. Then, also, we find certain harmless groups of moths imitating closely the outward appearance of species of stinging bees and hornets. And one remarkable case of mimicry is the well known instance of some perfectly inodorous South American butterflies, which perfectly reproduce the external appearance of other butterflies which emit a most offensive odor; the reason assigned for this latter phase of mimicry being the very feasible one that the inodorous forms are protected from the attacks of birds by their resemblance to their strong-smelling neighbors. As a last instance of this curious phase of animal organization, we may note the example furnished by those curious little fishes, the *Hippocampi*, or sea-horses—so named from the obvious resemblance of the form of the head to that of a horse—the bodies of which become covered with long streamers of certain kinds of seaweed; so that, when these fishes rest amid the seaweed-covered nooks of their marine grottoes, the presence of their streamers serves to render detection by their enemies no easy matter.

Referring to the explanation, if such can be afforded, of these mimetic resemblances, there can be little doubt that, viewed as to its ultimate use and purpose, the condition of mimicry serves in the most effective manner as a means of defense and protection to the animals so endowed. The resemblance of the colors of birds to that of their habitat presents an obvious instance of this purpose; as also does the more complicated example of the imitation, by scentless butterflies, of their odorous neighbors. But, as regards the exact means whereby the condition of mimicry is induced and perfected, or concerning the exact causes of its assumption and development, natural history science, in its practical aspect, remains silent; although the bolder march of theory and speculation may indeed lead us for a little way toward the solution of the problem. At any rate, there can be no difficulty to our clearly appreciating the workings of a great law of purpose and design in the production of mimicry, as serving to protect the weak and less powerful against stronger and better-provided animals.

Turning now to some lower forms of animal life, we find in such forms as the *Hydræ*, or common fresh-water polyps, the zoöphytes, sea-anemones, jelly-fishes, and allied forms, excellent examples of very specific means of defense and offense in animals. Within the tissues of the bodies of the foregoing organisms, when these tissues are microscopically examined, numerous little sacs or cells, varying in size and form, may be observed. To these cells the appropriate name of "thread-cells," or *cnidæ*, has been given. When their structure is investigated, each little cell is seen to possess an elastic wall of double nature; the inner layer of the wall being strong, while the outer one is of thinner and more delicate texture. The upper or open extremity of the inner layer of the sac is prolonged to form a kind of sheath, which protects and gives origin to a thread-like filament, from the presence of which, indeed, these cells derive their name. This thread, in the ordinary condition of the cell, is coiled up within the interior of the sac, and around its own sheath; and in many cases both thread and sheath may be discerned to be provided with minute spines or hooks. The cell itself, in addition, contains a fluid, amid which the thread is submerged.

Such is the essential structure of a thread-cell in its normal state of what we may term repose. When such a structure, however, is pressed or irritated in any way, the cell ruptures or bursts, the contained fluid escapes, and the thread and its sheath are quickly protruded or thrown out from the opening in the cell. If, now, the thread and fluid are observed to come in contact with any body of appropriate and assailable kind, such a body will exhibit certain symptoms which will indicate to us the probable nature of these curious cells. Thus, when the tentacles or feelers of the sea-anemone, or of any of the zoöphytes, come in contact with a minute or susceptible organism adapted for food, the organism is first observed to struggle to escape from the entwining filaments which encircle its body. Soon, however, its active exertions cease, and the victim appears paralyzed and incapable of helping itself, or of struggling longer with its captor. The thread-cells, in other words, have been discharging their miniature darts or "threads" into the body attacked; the fluid—in all probability of acrid or poisonous nature—has been poisoning the tissues of the struggling organism; and the observation has revealed to us that the functions of the cells are undoubtedly analogous to those of the serpent's fangs and poison-gland, in that they serve to paralyze and kill the prey.

As might naturally be supposed, the power of the thread-cells varies in different species and groups of the animals that possess them; but there are some forms of *Cœlenterata*—for thus the *Hydræ*, sea-anemones, and their allies, are collectively named—in which the stinging-cells are of sufficient size and power to inflict severe pain on man himself. Aristotle was fully aware of this latter fact when he named the jelly-fishes and their allies *Acalephæ*, or "nettle-like" animals. And bathers and swimmers, through instinct, if not thorough zoölogical knowledge, generally and wisely contrive to give the jelly-fishes a wide berth in their marine meanderings. The late Edward Forbes, in his humorsome manner, says of one species of jelly-fish, that, "once tangled in its trailing 'hair,' the unfortunate, who has recklessly ventured across the graceful monster's path, too soon writhes in prickly torture. Every struggle," he continues, "but binds the poisonous threads more firmly round his body, and then there is no escape;" for, as the naturalist informs us, even when the arms or tentacles are cast loose from the body of the jelly-fish, they "sting as fiercely as if their original proprietor itself gave the word of attack." The Abbé Dicquemare, an observant French naturalist, found that some species can only sting the more sensitive parts of the body, such as the eyes. But Forbes's remark of the abbé's experiment, that most people would prefer "keeping their eyes intact, to poking medusæ into them," will coincide, we imagine, with the opinions of most of our readers. It is equally worthy of remark that "appearances" in natural history, as in ordinary life, are apt to be "deceptive;" and, looking at the grace and beauty of the jelly-fishes, we could hardly credit them with such virulent powers.

The most notable offenders of the jelly-fish class, in respect of their stinging powers, are the *Physaliæ*, or Portuguese-men-of-war, as they are popularly termed—a group of beautiful oceanic forms, met with floating far out at sea, especially in tropical latitudes, and presenting the appearance of a bladder-like structure, provided with a crest and trailing streamers, and colored of the most ethereal and beautiful of hues. When the tentacles of a physalia are allowed to come in contact with the human skin, the thread-cells—which are of large relative size, and measure in diameter about the three-thousandth of an inch—sting so severely that the effects of the irritation may persist for a considerable time, and may give rise in some cases to very painful after-effects. The thread-cells in the tentacles of the common species of sea-anemones have no effect on the skin of man; but, as the writer has frequently demonstrated on his own person, if the tentacle be allowed to touch the more delicate mucous membrane of the lips, a slight stinging sensation, accompanied by temporary numbness, may be felt. To the curious this is worth trying.

Passing in review the higher groups of the animal kingdom, we find an endless variety of contrivances subserving offensive purposes, or limited to the milder purposes of defense. Shells, scales, and plates of every kind, with special modifications for special purposes, may thus readily be selected as examples; spines and allied armaments of all shapes and sizes; poison-secretions and fangs of centipedes and serpents, and the sting of scorpions and bees, possessing sure and sometimes deadly effect on those they attack; and, in quadrupeds, strong claws and teeth united to equally powerful muscles—such are a few examples of the endless stores of weapons contained in animal armories.—*Chambers's Journal.*

# SKETCH OF ALEXANDER BAIN.

PROFESSOR BAIN, of the University of Aberdeen, is a representative man of the modern school of English thought, who has done his best work in the field of psychology. His elaborate treatises upon the human mind now take a leading place in our literature, and are used as text-books in many colleges and universities. Besides this more special line of inquiry, to which Prof. Bain has given prominent attention, he has also been very active in the general field of higher education as lecturer, examiner, and author. He was born at Aberdeen, in 1818, and entered Marischal College, in the university of that town, in 1836, where he took the degree of M. A. in 1840. From 1841 to 1844 he taught as deputy the class of Moral Philosophy in Marischal College, and 1844–'45 he had charge of the class of Natural Philosophy in that institution. In 1845 he was elected Professor of Natural Philosophy in the Andersonian University at Glasgow. In 1847 he was appointed by the "Metropolitan Sanitary Commission" their assistant secretary, and in 1848 he was transferred to the same office in the General Board of Health, a post which he resigned in 1850. From 1857 to 1862 he held the position of Examiner in Logic and Moral Philosophy in the University of London. During several years from 1858 to 1870 he held the office of Examiner in Moral Science in the India Civil Service Department, and in 1860 he was appointed by the crown Professor of Logic in the University of Aberdeen. In 1864 he was reëlected examiner in the University of London, and continued to hold that position till 1869. Prof. Bain's first literary production is said to have been an article in the *Westminster Review*, published in 1840, and he subsequently contributed much to the pages of that periodical. In 1847–'48 he wrote text-books on astronomy, electricity, and meteorology, in Messrs. Chambers's school series, also several of Chambers's "Papers for the People," and the articles on "Language," "Logic," "The Human Mind," and "Rhetoric," in the "Information for the People." In 1852 he published an edition of the "Moral Philosophy of Paley," with dissertations and notes. "The Senses and the Intellect," his first independent and systematic work, appeared in 1855, and in 1859 was followed by "The Emotions and the Will," thus completing a new methodical exposition of the human mind. In 1861 appeared from his pen "The Study of Character," including an examination of phrenology. In 1863 he published an English Grammar, and in 1866 a "Manual of English Composition and Rhetoric." His more recent works are: "Mental and Moral Science," 1868; "Logic, Deductive and Inductive," 1870; and "Mind and Body," contributed to the "International Scientific Series," in 1873. In 1874 appeared "A Companion to the Higher English Grammar," "Examples and Discussions of Important Principles and Usages," intended as a help to the thorough mastery of English. Prof. Bain contributed the articles on "Logic" and "Mental Philosophy" to "Chambers's Encyclopædia," and contributed editorial notes to the recent edition of the works of James Mill. Prof. Bain was for many years the intimate friend and confidant of George Grote the historian, and was made by him heir in reversion (after Mrs. Grote's death) of all his copyrights. In connection with Prof. Croome Robertson, he edited Mr. Grote's posthumous work on "Aristotle," and he also edited Grote's "Minor Works," and prefixed to the edition an elaborate estimate of the character and writings of the historian. In connection with Dr. Taylor he is now engaged in a thorough revision of Arnott's "Physics," bringing it up to date, so that a new edition of this valuable and favorite work may be soon expected. He received the degree of LL. D. in the University of Edinburgh in 1869.

As a philosophic thinker, the influence of Prof. Bain is now very widely felt. He has made a powerful impression upon the mental science of the age by accepting the results of modern physiology and treating methodically of thought and emotion in connection with their physical concomitants. Though not disregarding the value of introspection, or the study of psychical phenomena in the changes of consciousness, he couples with this method the vigorous study of mental effects on their physical side, considering that there can be no mental science worth the name that does not carry its analysis down to the material conditions under which mind is manifested. The recognition of the corporeal nature as so fundamental a factor in mental science naturally drew his attention to the theory of organic development by which the higher organisms are explained on the principle of their derivation from the lower. This theory carries with it the necessary implication that the psychical nature of man, his intellectual faculties, emotions, and sentiments, are also derivative from lower conditions, and are only to be explained through the principle of descent. In the last edition of "The Emotions and the Will" this view is consequently adopted.

We give the readers of the Monthly an excellent likeness of Prof. Bain, probably the first that has appeared in this country. He is a man of slight stature, but of an active nervous temperament, a free and admirable talker, full of wit and anecdote, and a lively storyteller. He is broad and liberal in his opinions, and holds advanced views on the subject of education and university reform.

# CORRESPONDENCE.

### THE WATER-HAMMER.

*To the Editor of the Popular Science Monthly.*

SIR: The following phenomenon can, perhaps, be explained by yourself or one of your readers: I have a water-hammer, made of a straight tube of glass, about eighteen inches long and three-quarters of an inch in diameter. At the top of the tube there are two bulbs, the upper one about half the size of the lower, with only a narrow passage of about a sixteenth of an inch in width to connect the lower bulb with the tube, and the upper bulb with the lower. About one-third of the tube contains water. When the tube is inverted, and the water allowed to fill both bulbs, it will not, upon the tube being reversed, run out, but will remain in the bulbs for an indefinite time, until shaken or otherwise disturbed. This may be owing to adhesion simply, or, possibly, to capillary attraction, but it is not to this fact chiefly that I wish to call your attention. The water being in the bulbs, and the tube held with the bulbs upward, if a smart blow with the palm of the had be applied at the bottom of the tube, there arises, under certain conditions which I have been unable to determine, a ringing noise resembling sometimes the singing of a bird, sometimes the noise produced by a thin iron instrument—a fork, for instance—when knocked rapidly against an empty tumbler. During this time, no water escapes from the bulbs, but the water at the mouth of the lower bulb is violently agitated, as if small particles of air were quickly ascending to the height of a quarter of an inch in the bulb. Not a drop of water is displaced, the water remaining at the bottom of the tube not being perceptibly increased while the noise continues. It lasts sometimes from five to ten minutes, and it seems as though, under favorable conditions, it might continue indefinitely. Very frequently, however, the experiment does not succeed, though apparently all the conditions are exactly the same. Here, therefore, are two questions:

1. What is the reason why the water, when caused to enter the bulbs, does not flow out of them when the position of the tube is reversed, but remains stationary as if there was no such thing as gravity, and, in this case, a vacuum besides?

2. What is the reason of the singing noise above described? G. M.

New York, *March* 28, 1876.

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*To the Editor of the Popular Science Monthly.*

WILL you allow me to state the precise ground of objection to your criticism of my book, "The Sexes throughout Nature?" "What she proposes to do," you affirm, "is nothing less than to reduce the whole organic world, with all its vital and physical characters, into exact and demonstrable quantitative expression."

I only insist that, until science can offer us exact quantitative proof that the total of male characters is in excess of the total of female characters, no scientist should assume to determine, on scientific authority, that woman is inferior to man. I make no attempt to place my hypothesis, that, *in each species of being, the sexes are true equivalents*, on a "demonstrable quantitative" basis.

Though presented in the form of equations, and defended in a series of carefully-argued propositions, the theory waits to be tested experimentally and quantitatively. It assumes to be nothing but a provisional hypothesis, destined to be either confirmed or rejected, as it is found to agree or not to agree with the decisive facts of Nature. I merely offer various evidence in defense of the assumption that, physical powers compared with physical, and psychical powers with psychical, the female is everywhere the equal of the male of its own species.

Unlike but mutually-adapted physical growth and expenditure, including the functions of reproduction, are held to balance and equalize the physical well-being of the sexes. It is further claimed that their psychical powers, dependent upon and working through adapted organisms, are also thereby maintained in a perpetually-adjusted equilibrium. The hypothesis assumes true mental equivalence, which is secured through inherent, varying, constitutional provisions.

My sole claim to originality must lie in the attempt to briefly and insufficiently indicate *how* Nature has wrought to achieve a continuous and progressive balance of the sexes from the beginning until now. It remains to complete the work; to determine *how much* of one set of characters is the mathematical equivalent of counter-balancing quantities.

Extremely accurate and detailed estimates are doubtless out of the question. The simplest computations are so inexact that even the mean distance of the earth from the sun still awaits revision. However, "in time," science must be able to offer sufficiently accurate, incontrovertible proof that men and women are, or are not, intellectually peers.

A. B. Blackwell.

Somerville, N. J., *March*, 1876.

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## THE "NEW PHILOSOPHY" OF HEAT.

*To the Editor of The Popular Science Monthly.*

In opening a copy of Bailey's Dictionary, published in London in 1775, my eye fell upon the following: "Heat (according to the *New Philosophy*) very much consists in the rapidity of motion in the smaller parts of bodies, and that every way; or in the parts being rapidly agitated all ways. Its operation upon the senses we call *Heat*, and is estimated according to its relation to the organs of feeling, which motion of its small parts must be brisk enough to increase or surpass that of the parts of the sentient, for if it be more weak or languid, it is said to be cold."

I was under the impression that the theory concerning heat which involves this definition is of modern development. What is the truth on the subject?

E. R. Craven.

The doctrine which makes heat consist in molecular motion, or in an agitation of the minuter parts of which material things are constituted, is old as a *speculation*, but modern as a scientific demonstration. Locke said, more than a hundred years ago, "Heat is a very brisk agitation of the insensible parts of an object, which produces in us that sensation from which we denominate the object hot, so that what in our sensations is *heat*, in the object is nothing but *motion*." Similar views may be vaguely traced in the writings of Galileo, Bacon, Newton, Leibnitz, Descartes, Bernoulli, and Laplace. But they were unverified conjectures, and could not take their place among the principles of science until experimentally proved. This was first done by Count Rumford, in his celebrated experiments at the Munich Arsenal, and published in the "Proceedings of the Royal Society for 1798." But Rumford's results were ignored for half a century. Dr. Whewell published the history of thermotics in 1837, without mentioning him. He was far in advance of his age, both in his philosophical views regarding heat and the experimental evidence by which he sustained them. When, from 1840 to 1850, various physicists and chemists entered upon lines of research that led to the general doctrine of the convertibility or correlation of forces, the labors of Rumford began to be appreciated, and the truth concerning the nature of heat being proved in various ways, became accepted in science and part of a "new philosophy," in a sense quite different from that in which these terms were used in the last century.

# EDITOR'S TABLE.

### *THE RADIOMETER.*

We some months ago printed a paper describing briefly the leading features of Mr. Crookes's discovery of the mechanical action of light. We this month publish a more elaborate article under the same title, with new illustrations, in which the distinguished discoverer goes more fully into the subject, states how he was led into the investigation, explains the construction of the instrument, traces out the action of different kinds of rays, shows the value of the contrivance as a photometer or light-measurer, explains its magnetic and electrical relations and how its motions may be recorded, suggests its meteorological uses, and finally considers its results as determining the amount of the force of sunlight upon the earth. Nothing could better illustrate the wide and complex interactions and dependencies of natural phenomena than the circle of questions that is opened by the introduction of this ingenious invention.

The radiometer (so called because of its capacity of measuring radiations) is a very simple instrument (as will be seen by referring to Fig. 8, page 269), consisting of a small glass globe from which the air has been pumped out, and containing four arms supported at the centre by a fine point, and carrying at their extremities thin vanes or disks, white upon one surface and dark upon the other. When light from any source falls upon it the arms begin to revolve, the white surfaces approaching the light and the dark surfaces receding from it as if repelled or pushed away. We have before us a radiometer made by Geissler, the inventor of "Geissler's Tubes," which consists of a globe two and three-quarters inches in diameter, with its downward stem resting on a wooden base, the whole being ten inches high. It is in motion constantly in the daytime, propelled by the diffused light from the window, and, if the curtain be dropped and the room darkened, the faint light that comes in at the side maintains it in slow revolution. As the intensity of the light increases the motion is quickened, and when the instrument is placed directly in the solar rays the revolutions are so rapid that they cannot be counted. Mr. Crookes made one instrument so delicate that a single candle would drive it at forty revolutions per second.

In the hands of many the radiometer is now only a curiosity and a toy, yet to the physicist it is an instrument of great interest as displaying a new aspect of dynamical phenomena, and may help to explain still further the nature of the radiant forces, and perhaps throw light upon other questions. It is attracting much attention from scientific men, who may be expected in due time to report the results of their own reflections and experiments upon the subject.

### *SUNDAY AT THE CENTENNIAL EXHIBITION*

The exhibition at Philadelphia has many features of interest, one of the highest of which is that it stands out before the world in a moral and religious aspect as a tribute to the dignity, inspiration, and sacredness of conscientious and successful labor. The warriors, politicians, orators, have their honors elsewhere; the Centennial Exposition is an ovation to the "captains of industry." The multitudinous display is all due to the achievements of labor, to head-toilers and hand-toilers —the devotees and the heroes of science and art. Each product that is gathered in that great museum has had its history, which in most cases will show a long, laborious, painful struggle after perfection, by faithful study of the laws of Nature, manifested in the operations of forces and the properties of matter. Now, these laws of Nature are the laws of God, or there are no laws of God. The divine will is disclosed in the immutable ordinances of being, and the order of the world, or there is no such disclosure to man. And to seek to know the divine will as expressed in the laws by which things are governed, and to conform action and conduct to them, is the essence of religion, or there is no religion. The denial that this great gathering of the noblest fruits of the world's thought and industry has in it a religious element, and is grounded upon a religious basis, answers to our notion of atheism and heathenism. Can we indeed assert that those who have thrown light into the dark places of Nature that the earth might be subdued, and humanity elevated, and life beautified and enriched, have not been engaged in an eminently religious service? Shall we say that the Eternal Mind, in instituting the laws of material things—chemical, physical, biological—has claims upon our religious reverence, while the human mind in discovering and applying these laws to ends of beneficence is engaged in a non-religious work? If God framed the mysterious order around us and adapted the human mind to unfold itself by studying out these mysteries, can we render him any truer homage than is implied in the consecration of thought to these studies, and in carrying on the constructive and creative works which the resulting knowledge makes possible? No! we heartily agree with Carlyle when he says, "Older than all preached gospels is that ever-enduring evangel, work is worship."

The trophies of productive knowledge and inventive genius are brought together in the vast exhibition, and what are they but witnesses that men have studied faithfully and labored well? The honesty and integrity of human effort are attested in the processes and results. The laws of Nature hold true—there is never a break in the continuities of effect—and heat, light, air, affinities, cohesions, attractions, and all the properties of elements, and the habitudes of energy, never falter for an instant, and all goes on harmoniously and successfully. Who but the irreligious can fail to recognize the solemn implications of these wonderful results; and how otherwise can they be construed by the reverent mind than as God's immediate maintenance and indorsement of the work?

The exhibition has been planned and carried out for one purpose—to be seen and to become a source of instruction and elevation to the beholders. It is designed for all classes to come and examine its treasures, and learn its lessons. The public has been taxed to establish it for purposes of public use, to be attained only by opening its gates to all comers. Its influence is undoubtedly salutary and elevating and to be every way promoted. Attendance is expensive, difficult to many, and impossible to many more. It has been enormously costly that it might be greatly valuable; and its managers are bound to leave nothing undone to carry out its design, which is to be open to the inspection of the largest possible number of people.

Yet, strange to say, the commissioners who control it have decided that it shall be shut up fourteen per cent. of the available time! They have decided to destroy one-seventh of its usefulness. They decree that one day in the week nobody shall see it. Though so extensive that much time is required for even a partial observation of it, the managers determine that the little time visitors have shall be curtailed. And, what is worse, they shut it up the very day of all others when it would be most available to thousands. Though designed to honor labor, it is closed at the only time when multitudes of laborers have an opportunity to attend it.

And what is the reason of so apparently extraordinary and stultifying a course? After so much trouble to get it open, why do the commissioners shut it up this considerable portion of the time? The answer is, it is done in the name of religion! Religious people protest that its opening on Sunday would be a violation of the sacredness of that day, and a violation of the laws that enforce its religious observance. Influential religious bodies have passed resolutions and sent committees to Philadelphia to press this view upon the commissioners. Now, we strongly protest against this assumption that the opening of the exhibition any day of the week will be an irreligious act. The Jew may hold it wicked to visit the show on Saturday, and the Christian may hold it sinful to visit it on Sunday, and both may obey their consciences and stay away on the days they hold sacred; but to force their views upon people who think differently is not a dictate of religion but of persecuting bigotry. A century or two hence, in revising the "History of the Conflict," it will be contemptuously denied that religion was responsible for shutting up the Industrial Exhibition of 1876, against the people, and nullifying its usefulness one day in the week. It will be attributed to superstition, to theological influence and sectarian intolerance. It will be said it is a libel on religion to charge it with the narrowness and prejudice of the times when such a thing could be done.

The position of the Sunday question is simply this: there are two Sundays which we are called upon to recognize in different ways, and on totally distinct grounds, namely, the Sunday of rest from labor for secular reasons, and the puritanical Sunday, devoted to pious observances. The former is enforced by the state, on grounds of public and general utility; the latter is enforced by theological influences for reasons claiming to be religious, and stands upon an ecclesiastical basis. The secular Sunday—the Sunday of rest from labor—is an institution aiming to promote the social welfare, appealing to the sanctions of reason, and is enforced with the discretions of common-sense, and under limits which recognize the admissibility of a certain amount of labor for the general benefit. These are the considerations to which all parties appeal in advocating a day of rest, and they are the sole considerations by which legislators have any right to be moved in legally establishing it. Granting their right to ordain a general suspension of labor one day in the week, for the general good, they have no warrant to go a step beyond this in the direction of restraints upon the free action of individual citizens. They have no more authority to establish a particular religious day than to establish a particular religion. When people desist from work on Sunday, they comply with all that the state can justly require of them, and are left free to occupy themselves in any way they please, subject to the usual regulations of conduct which are in force at all times.

But ecclesiastical influence is constantly striving to turn the secular Sunday to theological account, and to invoke the interference of law with the freedom of citizens in religious matters. The history of the puritanical Sunday has been for centuries the history of meddling with the liberties of conduct, of the coercion of conscience, and the enforcement of observances on alleged religious grounds. The most innocent actions have been held as profanation of the Lord's day. All amusements were forbidden as wicked, and it was held as sinful to kindle the fire, or dress meat, or visit the neighbors, or walk abroad in the fields. Acts intrinsically proper have been construed as crimes if done on Sunday. The absurdities of sabbatarian legislation illustrate the grossest superstitions of the past. The following statement from Cox's "Sabbath Laws" represents the character and logic of the old practices: "At Aberdeen, in the month of November, 1608, a great panic arose by reason of an earthquake which had visited the city, and as the cause of the earthquake was distinctly traceable to the custom of salmon-fishing on Sunday, the proprietors of the salmon-fishings were summoned before the Session and solemnly rebuked." This may seem ridiculous, but do we not still hear of the judgments that follow Sabbath-breaking?

And it is important to note that, when viewed even theologically, the strictness of the Puritan Sunday is without authority. If the Old Testament is appealed to, the fourth commandment forbids work with emphatic detail on the seventh day of the week, but forbids nothing else. If the New Testament is appealed to, we find Christ nowhere establishing Sunday, but entertaining such latitudinarian views on the subject as to incur the reproaches of the pietistic Pharisees for Sabbath-breaking. And in reply to their puritanical notions he curtly told them that "the Sabbath was made for man, and not man for the Sabbath." Hence it has been justly said that "Christ himself did nothing more by word or act than protest against the superstitious abuses which in course of time had grown around the Sabbath." Paul exhorts the Colossians to independence of thought upon the subject, and to let no man judge them in respect of holidays, new moons, and Sabbath-days. It is alleged that there is no evidence that the early Christians kept Sunday, or the first day of the week, with Jewish strictness, but that it was first enforced by law in A. D. 386 by the Emperor Constantine, "who attached just as much importance to his own birthday as to the day of the Lord." But the puritanical spirit grew apace. "In proportion as the Church triumphed over paganism, so did the Christian days over those of the old world. The Church naturally used every effort to secure an increased respect for the days of its own creation. And though it was not till the time of Leo the Philosopher (889–910) that Sunday field-work was forbidden by an imperial law, in reference to public games and amusements the ascetic tendencies of the Church were earlier and more generally felt. The first innovation in this direction was the law of Theodosius the Elder, which included in its prohibition not only secular business but secular amusements. Abstinence, therefore, from toil and pleasure, having thus become the law of the Christian empire, the subsequent history of Sunday resolves itself simply into an extension of the principle."

Coming down to the Reformation, we find its master-spirits still struggling against the tendency to sabbatarian intolerance. "Cranmer speaks of Sunday and other days as mere 'appointments of the magistrates,' but considers *that* a sufficient reason for their observance." Tyndale says: "As for the Sabbath, *we be lords of the Sabbath*, and may yet change it into Monday, or into any other day as we see need, or may make every tenth day a holy day, only as we see cause why; neither need we any holy day at all if the people might be taught without." Luther said: "If anywhere any one sets up its observance on a Jewish foundation, then I order you to work on it, to ride on it, to dance on it, to do anything that shall remove the encroachments on Christian liberty." Calvin, in this, was equally liberal, and set an example by playing the game of bowls on Sunday. In all these cases we note the recognition of Sunday as a human institution, subordinate to the uses of man, while the puritanical Sunday, which represses recreations and stifles worldly enjoyments, is resisted and repudiated. The institution in its theological aspects is, therefore, destitute of any authoritative religious sanction. But, after centuries of contest between liberality and intolerance, the issue is still the same. As a day of rest from labor, Sunday is objected to by but few; and to the slave and the convict, and the millions of toil-worn operatives in factory, mine, and field, who earn their subsistence by the sweat of the brow, it is indeed a precious boon. To the multitudes doomed to a life of brutalized drudgery in barbaric times, it came as a blessed relief; and it is, perhaps, scarcely less necessary when the pressures of enterprise and competition would wear men out if no check was interposed. But the sour and gloomy Sunday of religious asceticism—the austere Sabbath of the sanctimonious Pharisee—requires to be resisted now as much as it was resisted by the founder of Christianity himself. In regard to the strict observance of Sunday, men have undoubtedly a right to do as they please under our guarantees of religious liberty; but they have no right to force their views upon others by perverting the legal day of rest to assumed religious objects, and by making it a hinderance to enjoyment and improvement on the part of those who desire so to employ it, and who are not to be judged by others in their manner of doing it.

It is objected to the opening of the exhibition on Sunday that it would involve the labor of many in attending to its operations, running trains, etc. But even the superstitious Jews had sense enough to interpret the fourth commandment as allowing works of necessity. A certain amount of Sunday labor is everywhere recognized as unavoidable, and as long as cooking, the running of Sunday cars and carriages, police surveillance, and the distribution of the mails, are carried on in Philadelphia under Pennsylvania laws, the objection to opening the exhibition because it would violate the law against Sunday labor is futile.

But we insist upon keeping the argument upon its highest grounds. We showed at the outset that the character and influence of such an exhibition are not only in the highest degree moral and salutary, but are also essentially religious; its opening every day of the week is therefore defensible on strictly religious grounds. We have furthermore shown that the religious reasons offered, for shutting it up on Sunday, are baseless. The considerations urged for closing are hence exactly those which require it to be free of access to the public—in other words, religion requires the opening. If it be alleged that the people would not see these higher meanings of the objects displayed, that only shows the defects of their religious training; and that there is all the more need of insisting upon this higher office of the exhibition. And if they are thus insensible to the moral and religious significance of so grand a collection of the noblest and most perfect products of human thought and skill, what more proper than to point out to them the elevated lessons that they teach? And if, instead of demanding that the exhibition shall be suppressed one day in the week, as if it were a public nuisance, the committees who have taken so deep an interest in the matter had asked the commissioners to arrange for religious services in one of the great halls, and to provide for discourses designed to bring out the higher instructiveness of the occasion and the demonstration, we think that they would have much better subserved the interests of true religion. The religious lesson that the commissioners have now lent themselves to inculcate is that people shut out from the Centennial buildings shall go to other buildings to think upon God; and that, therefore, the Centennial collection is a mere godless, sordid, anti-religious affair. But the people do not go to the appointed places of religious assembly. They crowd around the grounds by thousands, and occupy themselves in drinking at the saloons, and in cursing the bigotry of the management which forbids them to look upon the objects within, on the day that the State forbids them to work.

We fear, however, that any considerations of principle will be wasted upon the commissioners. The reasons they avow for forbidding entrance to the grounds on Sunday are not of a very elevated kind. In the report of the majority, after referring to the legislation of the country to prevent "secular business operations" on the "Christian Sabbath," they say: "Any action of this commission which is in conflict with the public sentiment expressed in these laws and in their practical observance will, in the judgment of your committee, so shock the moral sense of the country that it will jeopardize the success of the Centennial Exhibition, and turn the most powerful agencies throughout the land from active support to decided opposition. Your committee, therefore, recommend that the commission adhere to the policy which has heretofore governed its actions on this subject." It is not the "moral sense" of the community that would be shocked by opening the exhibition on Sunday. The "powerful agencies throughout the land" that would oppose it by deterring people from attendance on week-days, because those who wish it were admitted on Sunday, are not impelled by "moral sense," but by a narrow spirit of intolerance which is as immoral as the spirit of any other tyranny. The commissioners are of course bound to do every proper thing to insure the success of the exhibition; but they are not bound to eliminate all higher considerations from their conception of "success." We could wish them a little more elevation of view on this great national occasion; and in regard to their Sunday policy a little more of the spirit of Christ and Paul, Tyndale and Luther; a little more, indeed, of the genuine "spirit of Seventy-six."

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## LITERARY NOTICES.

The Ancient Régime. By Hippolyte Adolphe Taine, author of "A History of English Literature," "Italy," etc. Translated by John Durand. New York: Henry Holt & Co. Pp. 421. Price, $2.50.

Although M. Taine has made his reputation as a literary man, he must be credited with a genuine feeling for philosophical inquiry, and if not a scientist in the thorough sense, he nevertheless aspires to carry on his inquiries by scientific method. The present work is written from this point of view. Its author takes the modern standpoint in the study of history, and recognizes the futility of politics, when not guided by the principles of national development. His attitude of mind, and the spirit which he has brought to his task, are so admirably presented in the following passage from his preface, that we transcribe his own words. After stating that in 1849 he was twenty-one years old, and was called upon to vote, he remarks:

> "It was optional with me to be royalist or republican, democrat or conservative, socialist or Bonapartist; I was neither, nor even anything at all, and, at times, I envied so many people of faith who had the good fortune to be something. After hearing the various doctrines I felt that there was undoubtedly some void in my mind. Motives valid for others were not so for me; I could not understand how in politics one could make up his mind according to his predilections. Peremptory advisers constructed a constitution as if it were a house, according to the most attractive, the newest, and the simplest plan, holding up for consideration the mansion of a marquis, the domicile of a bourgeois, a tenement for workmen, barracks for soldiers, the communist phalanstery, and even a camp for savages. Each one asserted of his model, 'This is the true abode of man, the only one a man of sense can dwell in.' In my opinion, the argument was weak; personal fancies are not authorities. It appears to me that a house might not be built for the architect, nor for itself, but for the owner and occupant. To ask the opinion of the owner, to submit plans

to the French people of its future dwellings, was too evidently a parade or a deception: in such cases the question is tantamount to the answer, and, besides, had this answer been unconditioned, France was scarcely more at liberty to give it than I was; ten million ignorant men cannot constitute a wise one. A people on being consulted may indeed tell the form of government they like, but not the form they need; this is possible only through experience; time is required to ascertain if the political dwelling is convenient, durable, proof against inclemencies, suited to the occupant's habits, pursuits, character, peculiarities, and caprices. Now, as proof of this, we have never been content with our own; within eighty years we have pulled it down thirteen times in order to rebuild it, and this we have done in vain, not having yet found one that suits us. If other people have been more fortunate, if in other countries many political institutions are durable and last indefinitely, it is because they have been organized in a peculiar manner, around a primitive and massive nucleus, supported on some old central edifice, many times repaired, but always preserved, enlarged by degrees, adapted and modified, according to the wants of the inhabitants. None of them were built at one stroke on a new pattern, and according to the provisions of reason alone. We must perhaps admit that there is no other way of building permanently, and that the sudden concoction of a new constitution, suitable and durable, is an undertaking surpassing the forces of the human mind. In any event, I came to the conclusion that if we should ever discover the one we need it will not be by the means in practice. The point is to *discover* it, if it exists, and not to put it to vote. In this respect our preferences would be fruitless; Nature and history have chosen for us in advance; it is for us to adapt ourselves to them as it is certain they will accommodate themselves to us. The social and political mould into which a nation may enter and *remain* is not subject to its will, but determined by its character and its past."

From this point of view, M. Taine came to the conclusion that his country needed, first of all, to be studied systematically, and the present work is the first of a series which together are designed to constitute a philosophic study of modern France. The "Ancient Régime," the volume now published, is devoted to the pre-Revolutionary period, and is to be followed by a work on the French Revolution, which will in turn be preparatory to a third, on the "New Régime," designed to interpret recent and contemporary France. The enterprise will be executed with the undoubted ability that distinguishes this brilliant and versatile author, and will permanently identify his name with modern French history. At any rate, the present book is instructive and fascinating to a remarkable degree. It is at the same time a vivid and life-like picture of French society anterior to the Revolution, and a subtile and comprehensive analysis of the forces at work in it, that issued in the revolutionary outbreak. A marked characteristic of the work is the freshness of a large portion of its materials, resulting from the author's indefatigable researches among hitherto unexplored masses of original correspondence, documents, and records.

The Warfare of Science. By Andrew Dickson White, LL. D. New York: D. Appleton & Co. Pp. 151. Price, cloth, $1; paper, 50 cents.

The admirable lecture of President White upon this subject, which was published in The Popular Science Monthly for February and March, is now issued in a separate form, with important additions, by the author. Although a small book, it covers broad ground, and treats the subject in a decisive way. The thesis maintained is this: "*In all modern history, interference with science in the supposed interest of religion, no matter how conscientious such interference may have been, has resulted in the direst evils both to religion and to science, and invariably. And, on the other hand, all untrammeled scientific investigation, no matter how dangerous to religion some of its stages may have seemed, for the time, to be, has invariably resulted in the highest good of religion and of science.*" In working out the proof of these propositions, President White has traversed an extensive field of historical resources, dealing successively with the rise and progress of geography, astronomy, chemistry and physics, anatomy and medicine, geology, political economy, agriculture and engineering, and scientific instruction. The whole discussion has been carefully gone over, and much amplified in its present form. In his preface the author says: "I have now given it careful revision, correcting some errors, and extending it largely by presenting new facts and developing various points of interest in the general discussion. Among the subjects added or rewrought are: in astronomy, the struggle of Galileo and the retreat of the Church after its victory; in chemistry and physics, the compromise between science and theology made by Thomas Aquinas, and the unfortunate route taken by science in consequence; in anatomy and medicine, the earlier growth of ecclesiastical distrust of these sciences; in scientific education, the dealings of various European universities with scientific studies; in political and social science, a more complete statement of the opposition of the Church, on scriptural grounds, to the taking of interest for money; and in the conclusion, a more careful summing up."

The distinguishing feature of this little volume, and which will make it eminently valuable and useful at the present time, is its copious and careful notes, which give authoritative support to the argument. Nothing important is left to rest upon mere assertion. The battle that Science has had to fight from the beginning, and without remission, with ignorance, prejudice, and intolerance, inspired and directed by ecclesiastical influence, is vividly delineated in the text, and the positions taken are so fortified by citations from works of the highest character as to leave little room for further controversy. That the history of Science has been throughout a struggle with the theologians, and that the Bible has been used by devout believers in its infallible inspiration to crush out the results of scientific inquiry, are perfectly well known; while that science is still dreaded and denounced on religious grounds, and that the Bible is still extensively appealed to against its conclusions, are now so obvious that there is certainly no reason for doubting its employment in the same way, in less enlightened times. But there are so many who are inclined to forget, and belittle, and explain away the uglier features of the past conflict, that it becomes necessary to array the evidence of it in book and page, chapter and verse, as President White has done. Nothing is to be gained, at any rate, by ignoring historic truth, and bigotry and superstition still offer too vigorous a resistance to the advance of rational inquiry to make it desirable that we should quite forget the painful lessons of the past.

Die Hundertjährige Republik. Von John H. Becker. Augsburg: Lampart & Co. Pp. 440.

The author of the "Centennial Republic," during a sojourn of several years in the United States, was a critical observer of our social and political life. The result of his observations is a merciless exposure of all the vices and defects of republican institutions as they exist in this country. The work is in reality a pamphlet intended to influence the minds of Germans living at home, and to dissuade them from emigrating to the United States. Mr. Becker has three chapters on the condition of the working-class; several chapters on politics and government, rings, carpet-baggery, corruption, the lobby; finally, he treats of the family, education of children, and a number of other subjects. The author is an advocate, and does full justice to the cause he defends; the brighter side of American life is not his concern.

French Political Leaders. By E. King. *Also*, German Political Leaders. By Herbert Tuttle. Pp. 264. New York: Putnams. Price, $1.50 each.

These two volumes are numbered respectively III. and IV. in Putnam's series of "Brief Biographies," designed to acquaint the American public with the characters and services of eminent politicians and statesmen abroad. In vol. iii. we have sketches of twenty-three of the foremost political leaders of France, and in vol. iv. of nineteen men prominent in the political life of Germany. Both Mr. King and Mr. Tuttle have enjoyed the advantage of personal acquaintance with several of the subjects of their biographies; in all cases they have had the best opportunities for studying the men whose lives they describe. They are no transcribers of biographical notes and dates, their aim being rather to portray character than to inform the reader of the dry and impertinent details of a man's career.

History of the United States. By J. A. Doyle. New York: Holt. Price, $1.40.

This is beyond question the best manual of the history of the United States that has yet been written. The style is plain and marked by directness; and the author usually assigns to events their true proportions, as viewed from the standpoint of the impartial historian. Four graphical maps exhibit—1. The changes in territory; and, 2. The distribution of population in 1790, 1830, and 1870.

THE CHILDHOOD OF RELIGIONS: EMBRACING A SIMPLE ACCOUNT OF THE BIRTH AND GROWTH OF MYTHS AND LEGENDS. By EDWARD CLODD, F. R. A. S. New York: D. Appleton & Co. Pp. 288. Price, $1.25.

THE author of this book published, two or three years since, a little volume entitled "The Childhood of the World," in which he presented, in a familiar way, designed for perusal by the young, the modern doctrine of the antiquity of the world, and something of that which is now regarded as known concerning the primitive condition of man. The success that attended his former undertaking has led him to break into another and a kindred field, and to present, in a popular and readable form, what is considered to be known in relation to primitive religions. The author regards the two works as but parts of one argument, and the present volume as the natural and necessary outgrowth of the former. Of the need and purpose of such an exposition he remarks, at the opening:

> "The question which forces itself upon all who are interested in the education of the young is what they shall be taught regarding the relation of the Bible to other sacred scriptures, and to the declarations of modern science when they fail to harmonize with its statements; and it is as a humble contribution to the solution of that question that the present and preceding volumes have been written. In an age which has been truly characterized by a leading thinker as one of 'weak convictions,' it seems to me incumbent on those who, in accepting the conclusions to which the discoveries of our time point, regard the inevitable displacement of many beliefs without fear, because assured that the great verities remain, to be faithful to their convictions, and to show that the process of destruction is removing only the scaffolding which, once useful, now obscures the temple from our view. In the absence of any like elementary treatise upon subjects regarding which much ignorance and apathy prevail, and the treatment of which is at present confined to works for the most part high-priced, and not always accessible, I hope that this book may not be regarded as needless, however far it falls short of the requirement which appears to me to exist, and which it ventures to temporarily supply."

The book is very plainly written, and gives a great deal of interesting information about myths and legends of the creation, religious beliefs of the Aryan or Indo-European nations, the religion of the ancient and modern Hindoos, Buddhism, and the ancient religions of Persia, China, and the Semitic nations. Much is said upon these subjects nowadays by learned men, and Mr. Clodd's volume is a good popular introduction to this field of literature.

THE PHYSICAL BASIS OF IMMORTALITY. By ANTOINETTE BROWN BLACKWELL. New York: G. P. Putnam's Sons. Pp. 324. Price, $1.50.

THIS volume is an intrepid attempt to establish the doctrine of personal immortality on the scientific basis of modern physical theories. The indestructibility of matter and force, and the existence of atoms or units, are the principles Mrs. Blackwell employs as the foundation of her argument. We cannot here analyze it, but will give the author's standpoint in her own words:

> "It must be a part of my effort to offer sufficient evidence that actual indestructible centres of force do exist in Nature; and that no force is or ever can be, during the present order of natural events, separated from its own individual centre of activities. If this form of the atomic theory can be proved; if atoms can be shown to exist, and to persist in the midst of all changes, these atoms then become the unshaken basis of a personal immortality. We have only to further show that there are centres of atomic force, some of whose modes of energizing are sentient modes, and the whole case will be gained" (page 89).
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> "Mind is matter and something more. *Every mind is an indestructible material unit, constituted by allied force and extension, jointly conditioned with sentient force or consciousness.* The whole is an indivisible and immortal conscious personality" (page 175).

WILLIAM WHEWELL, D. D., MASTER OF TRINITY COLLEGE, CAMBRIDGE. AN ACCOUNT OF HIS WRITINGS, WITH SELECTIONS FROM HIS LITERARY AND SCIENTIFIC CORRESPONDENCE. By I. TODHUNTER, M. A., F. R. S. Two Vols., 416 and 439 pp. New York: Macmillan & Co. Price, $9.

WE have long waited for a life of Dr. Whewell, and although we have not found it in these volumes, in the usual sense of the biography, yet we have here what may be called a history of his intellectual life, as disclosed in the informal and fragmentary passages of an extensive correspondence. Sir John Herschel has said of Dr. Whewell that "a more wonderful variety and amount of knowledge in almost every department of human inquiry was perhaps never in the same interval of time accumulated by any man." Of this, his numerous and learned publications bear ample witness, and it is of course from these that the intellectual character of the man is to be properly deduced. But our interest in him is greatly heightened by the glimpses of a strong personality, which these volumes reveal in his free and extensive intercourse with the intellectual celebrities of the time. We have no space for illustrations of the quality of these most readable books, but the following reference to Dr. Lardner will give a sample of their general spiciness:

> "Mr. Herschel's discourse" (on natural philosophy) "was published in Lardner's 'Cabinet Cyclopædia,' and he afterward contributed to the same series an elementary 'Treatise on Astronomy.' Prof. Whewell was not quite satisfied with the channel which his eminent friend thus accepted for his writings. Dr. Lardner was a man of scientific attainments, and of considerable ability for popular exposition; his importunity in urging the fulfillment of the promises which he obtained of coöperation in his 'Cyclopædia,' and his name Dionysius, which it was conjectured he had himself modified from the more familiar Denis, naturally led to the appellation *tyrant*, which was given to him in a good-tempered manner by Southey and other literary men of the period. He made various attempts to induce Prof. Whewell to join his staff, and in particular during the present year wished to engage him to write on political economy; but the applications were in vain. Prof. Whewell, perhaps, mentioned the matter to Mr. Jones, as we may conjecture from a sentence in a letter from him: 'I should like to write a treatise for the tyrant if he would wait two or three years, but he shall not have the *prémices* of my speculations.'"

### THE CHRIST OF PAUL; OR, THE ENIGMAS OF CHRISTIANITY. By C. REBER. New York: Somerby. Price, $2.00.

THE principal topics considered in this volume are, the influence of the Essenes and Therapeutæ on the development of the Christian system; the origin of the four Gospels; the influence of Irenæus on Christian beliefs; the dogma of the Trinity; the origin of the Episcopate and of the Papacy; the miracles attributed to Christ, the Apostles, and their successors.

### CONNECTION OF METEOROLOGY WITH HEALTH. By WILLIAM BLASIUS.

IN this paper the author strives to assign a philosophical reason for "the well-known fact" that, during all ages, cities, where topographical impediments do not interfere, extend, as a general rule, from east to west, and that the wealthiest people are always in the advance.

### LESSONS FROM NATURE, AS MANIFESTED IN MIND AND MATTER. By ST. GEORGE MIVART, Ph. D., F. R. S. Pp. 462. New York: D. Appleton & Co. Price, $2.

THE title of this book is somewhat misleading. We should expect to find in its pages a cool, didactic statement of the result of observations and studies in natural history, perhaps, or in some of the familiar aspects of Nature. But, instead of simple lessons or inculcations from natural things, presented in a quiet and instructive form, we have a book full of rancorous controversy and bitter polemics. Mr. Mivart has achieved some reputation as an anatomist and biologist, and is by no means destitute of expository power, but the discussions in this volume show that he is more a theologian than a scientist, more a bigot than a philosopher, and more fond of fighting than teaching. He makes a series of vindictive assaults upon men with whom he does not agree, and then names the result "Lessons from Nature." A writer in the *Quarterly Journal of Science* administers to Mr. Mivart a well-merited castigation for his unscrupulous course in dealing with contemporary thinkers, and we publish a portion of the article under the title of "Bigotry and Scientific Controversy." The writer treats him unsparingly, but we think justly, and condemns in terms of merited severity the practice, not yet extinct, of appealing to the *odium theologicum*, which "in its most malignant form pervades the entire book."

"Lessons from Nature" is a discussion of the tendencies of modern theories which are associated with the names of Darwin, Spencer, Mill, Helmholtz, Huxley, Lewes, and others, which are variously characterized by this author as immoral, irreligious, materialistic, and atheistic. The course of thought is more metaphysical than physical, and the volume derives but little value from the scientific acquirements of the writer. Indeed, he had already told us in his "Genesis of Species" all that he has to say in opposition to the views of Darwin, and here it is only restated with the garnish of abuse and invective. But, although himself committed in the "Genesis of Species" to the doctrine of Evolution, and saying, as he does at page 16, "the prevalence of this theory need alarm no one, for it is, without any doubt, perfectly consistent with the strictest and most orthodox Christian theology," yet his present book is a battle with the Evolutionists, and the consequences of the theory, and in the interest of Catholic orthodoxy. And the champion proves to be not a whit too good for the cause he represents. In the survivals from savagery the same spirit only changes its instruments—the tomahawk is replaced by the pen. Those who delight in vicious polemics will find Mr. Mivart's volume an unusual treat.

A New Encyclopædia of Chemistry, Theoretical, Practical, and Analytical, as applied to the Arts and Manufactures. By Writers of Eminence. Illustrated with numerous Steel-Cuts and Engravings. Complete in 40 Parts. 50 cents each. Philadelphia: Lippincott & Co.

We have received five numbers of this work, which promises to be valuable and exhaustive. It is constructed upon the basis of the elaborate work, "Chemistry as applied to the Arts and Manufactures," by the late Dr. Muspratt, which was published twenty years ago. But twenty years antiquates a chemical book, especially when it deals with the application of science to the arts. Numerous and important improvements in chemical manufacture have been made within the last quarter of a century, which make new statements indispensable to those who are concerned with practical processes. The thoroughness of treatment adopted in this work is illustrated by the fact that nearly the whole of the first part is devoted to acetic acid and its salts. Alcohol occupies the second part; and alum, ammonia, aniline dyes, antimony, and arsenic, are treated with a corresponding fullness. In their prospectus the publishers remark: "Convinced that the infinite variety of subjects now embraced in such a work could be adequately treated by no one writer, however learned or painstaking, the assistance of the leading chemists of the present day has been secured, as well as of writers who are practically acquainted with all the details of our great manufactures." But no names are given, either of editor or collaborators. Something would, no doubt, be gained by knowing to whom the execution of so large an enterprise has been intrusted, but we admire the pluck that puts the work forth—and a subscription-book at that—without the parade of names, and lets it go squarely upon its merits. It deserves to succeed.

Angola and the River Congo. By J. J. Monteiro. With Maps and Illustrations. Pp. 354. New York: Macmillan & Co. Price, $2.50.

We have not seen lately a more thoroughly interesting and instructive book of travels than this. The author spent several years in the country he describes, and his travels extended from the Congo River on the north, down the coast through about 10° of latitude. Most of his time was spent among the trading-towns at the mouths of rivers and along the coast, but he had frequent opportunities of studying the simple-minded savages of the interior. He found the natives kindly disposed if well treated. He was accompanied by his wife in his journeys, to whom the book is dedicated in a few touching and appropriate words. His travels seem to have been connected with a discovery made by himself in 1858, that the bark of the baobab-tree is of value in the making of paper. Many parts of the regions visited were covered by forests of this tree.

Among the natives fetichism prevails everywhere. Anything, as a tree, or animal, or an old rag, may be a fetich. No body dies a natural death, but is fetiched.

These people are not degraded, but represent a low stage of culture. They are undeveloped—not distinguished so much by the presence of positively bad as by the absence of good qualities. They are strangely wanting in the feelings:

"The negro knows not love, affection, or jealousy. I have never seen a negro manifest the least tenderness to a negress. They have no words or expressions in their language indicative of affection or love. Their passion is purely of an animal description, without affection. Mothers rarely play with or fondle their babies; as for kissing them, such a thing is not known; yet I have never seen a woman grossly neglect her child."

The book abounds with information concerning the climate, productions, physical geography, and general natural history of the region, and is a treasure equally to the general reader and to the student of this part of the vast African wilderness.

### A PRACTICAL TREATISE ON ROADS, STREETS, AND PAVEMENTS. By Q. A. GILLMORE, A. M. Pp. 258. New York: D. Van Nostrand. Price, $2.

A MUCH-NEEDED and most excellent little manual. There is no better measure of civilization than the state of the highways in city or country, and judged by that standard the American people are not much advanced. Bad roads prevail—roads badly laid out, badly constructed, and kept in bad order—and, while this general badness is an enormous burden upon the community, involving waste of horse-flesh, vehicles, time, and obstruction of business, there is still a degree of ignorance concerning the mechanics of the subject that is surprising among a people who make such large pretensions to enterprise. There are well-established principles in road-laying, road-making, and road-management, the violation or neglect of which entails such serious losses that it is a matter of public economy to wake up any community to the importance of the subject. General Gillmore's book gives the latest information regarding it, within moderate limits, and he thus states the leading objects that have been kept in view in its preparation:

> "1. To give within the compass of one small volume such descriptions of the various methods of locating country roads, and of constructing the road and street coverings in more or less common use at the present day, as will render the essential details of those methods, as well as certain improvements thereon of which many of them are believed to be susceptible, familiar to any intelligent non-professional reader. 2. To make such practical suggestions with respect to the selection and application of materials, more especially those with the properties and uses of which builders are presumed to be the least acquainted, as seem needful in order to develop their greatest practical worth and realize their greatest endurance. 3. To institute a just and discriminating comparison of the respective merits of the several street pavements now competing for popular recognition and favor, under the varying conditions of traffic, climate, and locality, to which they are commonly subjected."

### USES OF A TOPOGRAPHICAL SURVEY OF NEW YORK. By JAMES I. GARDNER.

THE uses of a topographical survey of the State, as set forth in this paper, are as follows: 1. Such survey is a necessary basis for equalizing taxation; 2. It will establish imperishably every property boundary in the State; 3. It will make it possible to describe correctly the area of real estate conveyed by a deed; 4. It will afford facilities for proper plans of suburban drainage and water-supply, and extensions of village streets and country roads; 5. It will furnish a basis for a scientific survey of the State's resources.

### THE AMERICAN STATE AND STATESMEN. By W. G. DIX. Boston, Estes & Lauriat. Price, $1.50.

IN his preface the author asks the question, "Have we not been trying to get along somehow for nearly a hundred years without any principle of government?" If so, it is full time to discover a principle of some kind. From the titles of two or three chapters, such as "Christianity the Inspirer of Nations," "America a Christian Power," "Materialism the Curse of America," it would appear that the author's prescription for all our political ills is Christian statesmanship. And, when the nation has been saved, we must head a grand crusade against Mohammedan sovereignty in Eastern Europe, Western Asia, and Northern Africa!

### THE BIBLE AND SCIENCE. By J. WEISS. *Also*, THE SYMPATHY OF RELIGIONS. By T. W. HIGGINSON.

THESE are tracts published by the Free Religious Association, Boston. They are intended to popularize the ideas and aims of a body of thoughtful men and women, and are sold at the low price of $3.00 per hundred copies. The tracts already published are four in number, including, besides the two named above, one on "Taxation of Church Property," by James Parton, and one on "Transcendentalism," by the late Theodore Parker.

### NOTES ON THE YUCCA-BORER. By C. V. RILEY, Ph. D. Pp. 23. St. Louis: R. P. Studley.

THE roots or subterranean trunks of yuccas are often found to be hollowed out along the axis; this tunneling is the work of the yucca-borer (*Megathymus yuccæ*). In the paper before us, Prof. Riley gives the results of his studies upon this insect. He is inclined to regard the yucca-borer as the representative of an ancient type from which are derived on the one hand the *Castnians*, on the other the *Hesperians*.

EXERCISES IN ELECTRICAL AND MAGNETIC MEASUREMENT. By R. E. DAY, M. A. Pp. 130. London: Longmans, Green & Co.

THIS little manual is intended for the use of students commencing a course of laboratory practice, or preparing themselves for actual work in connection with electric telegraphy. The author employs almost exclusively the nomenclature and system of units approved by the committee of the British Association, but he also gives exercises in the conversion of these units into the units of various other systems, and *vice versa*.

FIRST ANNUAL REPORT OF THE JOHNS HOPKINS UNIVERSITY.

THIS Report contains the Statement of the Trustees, the Report of the President of the University, Daniel C. Gilman, a letter from P. R. Uhler on Collections in Geology and Natural History, and a Preliminary Announcement of courses of study, fellowships, scholarships, etc.

## PUBLICATIONS RECEIVED.

The Wages Question. By Francis A. Walker. New York: Holt & Co. Pp. 428. Price, $3.50.

Geological and Geographical Survey. Report of F. V. Hayden for the Year 1874. Washington: Government Printing-Office. Pp. 515.

Annual Record of Science and Industry for 1875. By Spencer F. Baird. New York: Harpers. Pp. 946. Price, $2.

Elements of Psychology. By H. N. Day. New York: Putnams. Pp. 248. Price, $1.50.

Spirit Invocations. By P. A. Putnam. Boston: Colby & Rich. Pp. 256. Price, $1.25.

The Historical Jesus of Nazareth. By M. Schlesinger, Ph. D. New York: Somerby. Pp. 98. Price, $1.

High Masonry Dams. By J. B. McMaster, C. E. New York: Van Nostrand. Pp. 132. Price, 50 cents.

Geology of Portions of our Western Territory. By G. K. Gilbert. Pp. 312.

The Geology of Route from St. George, Utah, to Gila River, Arizona. By A. R. Marvine. Pp. 30.

The Geology of Portions of our Western Territory. By E. E. Howell. Pp. 70.

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## MISCELLANY.

**Destruction of the Buffalo.**—The average annual destruction of buffaloes during the last thirty or forty years is estimated by a writer in the *Penn Monthly* at between three and four millions. During the season of 1872–'73 no less than two thousand hunters, it is said, were engaged in hunting the buffalo along the line of the Atchison, Topeka & Santa Fé Railroad alone. By these men at least 250,000 buffaloes were slain, simply for their hides, the carcasses being left untouched on the plains. At this rate, the bison will have utterly disappeared before many years, unless Government interferes to prevent this wasteful slaughter. As yet, neither the central Government nor any of the States have taken any effectual measures to prevent the extermination of the noble animal. The author of the article in the *Penn Monthly* suggests that the traffic in hides might easily be checked and controlled by law. The killing of buffaloes should be restricted, he says, to certain seasons of the year, and the destruction of the females and young wholly prohibited. Further, he would have it made a grave offense to kill a buffalo at any time wantonly, or without properly utilizing it. Then, certain portions of the public lands now within the range of the buffalo might be made a preserve, wherein no buffaloes should on any condition be killed.

**Distribution of the Rocky Mountain Locust.**—Prof. Riley fixes the southern limit of the Rocky Mountain locust's ravages at the 44th parallel of latitude and the eastern limit at the 103d meridian. The conditions preventing the permanent settlement of this insect in regions outside of the above limits are considered by Prof. Riley in his eighth annual report on the insects of Missouri. The native home of this locust he takes to be the higher treeless and uninhabitable planes of the Rocky Mountains—a sub-alpine habitat with dry and attenuated atmosphere. Now, a migration of insects accustomed to such conditions into a more dense and humid atmosphere must prove fatal to them. But another barrier to their permanent multiplication in the more fertile country to the southeast is found in the greater duration there of the summer season. As with annual plants, so with insects (like this locust) which produce but one generation annually and whose active existence is bounded by the spring and autumn frosts, the duration of active life is proportioned to the length of the growing season. "Hatching late and developing quickly in its native haunts, our Rocky Mountain locust, when born within our borders (and the same will apply in degree to all the country where it is not autochthonous), is in the condition of an annual northern plant sown in more southern climes; and just as this attains precocious maturity and deteriorates for want of autumn's ripening influences, so our locust must deteriorate under such circumstances. If those which acquired wings in Missouri early last June had staid with us long enough to lay eggs, even supposing them capable of doing so, those eggs would have inevitably hatched prematurely, and the progeny must in consequence have perished."

**Fight between a Mouse and a Scorpion.**—Frank Buckland, having witnessed the rare spectacle of a combat between a mouse and a scorpion, gives in *Land and Water* the following description of the fight: "The mouse having been dropped into the jar containing the scorpion, the battle at once commenced by the scorpion assuming the offensive. He made a lunge with his sting and struck the mouse. This woke up the mouse, who began to jump up and down like jack in the box. When he became quiet, the scorpion again attacked the enemy, with his claws extended like the pictures of the scorpion in 'The Signs of the Zodiac.' He made another shot at the mouse, but missed him. I then called 'Time!' to give both combatants a rest. When the mouse had got his wind, I stirred up the scorpion once more, and, as 'the fancy' say, 'he came up smiling.' The mouse during the interval had evidently made up his mind that he would have to fight, and not strike his colors to a scorpion as he would to a cat. When, therefore, the scorpion came within range, the mouse gave a squeak and bit him on the back; the scorpion at the same moment planted his sting well between the mouse's ears on the top of his head. The scorpion then tried to retreat, but could not, for one claw had got entangled in the fur of the mouse. The mouse and scorpion then closed, and rolled over each other like two cats fighting, the scorpion continually stabbing the mouse with his sting, his tail going with the velocity of a needle in a sewing-machine. When the scorpion got tired, the mouse got hold of his tail with his teeth and gave it a sharp nip. The mouse seized the opportunity, and immediately bit off two of the scorpion's side-legs. He then retired, and began to wash his face. I had expected, of course, that the poison of the scorpion would have killed the mouse, but he didn't seem a bit the worse for it. When I examined him the next morning he was quite lively and well, and had nearly eaten up the whole of the scorpion for his breakfast. Of course I rewarded the mouse for his plucky conduct by giving him some milk, and by letting him go in a place where it was not likely the cat would find him."

**Labor at the South African Diamond-Fields.**—The exploitation of the diamond-fields of South Africa promises to exert a mighty influence on the native populations living north of Griqualand. No sooner had the demand for labor arisen at the diggings than vast numbers of the races known as Mahawas, who live between the twenty-third and twenty-fourth parallels of south latitude, poured down from the country bordering on the Limpopo, and eagerly took service with the diggers. "They came in large bodies," says Mr. J. B. Currey, secretary to the government of Griqualand West, "often as many as two thousand in a month, arriving in a wretched state of emaciation." They wear no clothing save a cincture round the loins. They stay about six months, and then they are sleek, well-made, and often powerful men. They are very thrifty, and generally have from eight to ten pounds in money when the time for their departure arrives. This they expend in purchasing guns, powder, and lead, old military uniforms, beads, brass wire, and perhaps a little food, and set out for their own country, each man staggering under his burden. From the Mahawas the tidings of work and pay at the diamond-fields spread to other tribes living farther north, and in the early part of 1874 appeared groups of Makalakas from the great plains in latitude 20°, a race said to be without chiefs or laws or organization of any kind whatever. Still, degraded as is their condition, they seem to possess some remains of a more civilized state, and to show signs of an intelligence superior to that of the Mahawas. Parties of these people continued to arrive during 1874 and 1875, and in the middle of the latter year came the first party of the Maschonas, large, powerful, jet-black men, from latitude 18° on the southern bank of the Zambezi.

Remarking upon this curious movement of the natives, Mr. Currey observes:

> "And this great stream of native labor returns, after a few months, to the great ocean from which it flowed, bearing with it, as is inevitable, some traces of the strange lands through which it has passed, and some tinge of the things with which it has come in contact. We cannot prevent this, even if we would. For good or for evil these natives have tasted of the tree of knowledge, and know that they are naked. They go back, with something to tell, and the strange stories that must be repeated from hut to hut and village to village, the distorted accounts which must be spread of our religion and our laws, our virtues and our vices, our manners and customs, will produce results greater than any that all the missionaries of Europe could effect in a century. Events novel and rapid, which we have had no power to control, have unexpectedly placed us in immediate communication with new tribes, and our connection with them entails results which no indifference can ignore, and from which no timidity can escape."

**Natural History of the American Antelope.**—From an interesting paper in the *American Naturalist*, by Judge Caton, we select the following notes upon the natural history of the American antelope: The animal is not a native of the Old World, and is confined to a very limited portion of the New. In size the prong-buck, or American antelope, is considerably smaller than the Virginia deer, the adult male rarely exceeding four feet in length from tip to tip, and three feet in height to the top of the shoulder. The hairs of this animal differ from those of most of the hollow-horned ruminants, and possess the extreme characteristics of those of the deer. They are hollow except near the roots and extreme points, and are filled with a sort of light pith, like that found in the quill of the turkey. The hairs are non-elastic and fragile, in this respect resembling more those of the caribou than of any other quadruped. The entire absence of the hind or accessory hoof distinguishes the prong-buck from both the deer and the antelope. A very important feature of the prong-buck is its glandular system, from which is emitted a rather pungent odor.

The eye of the prong-buck is exceptionally large—much larger than that of the deer, the ox, or the horse. The entire exposed part of the orb is intensely black, with a mild and gentle expression. The animal is the swiftest-footed of all known quadrupeds, but it cannot continue the race at high speed for a great length of time, although for a few miles or a few minutes its career seems like the flight of a bird. While it can make astonishing horizontal leaps, even from a standing position, it cannot or will not make high vertical leaps. The author thinks that it could not under any circumstances be driven over an obstruction a yard in height. The most interesting of all its characteristics is its horns. These appendages are given to both male and female, but in the latter they are scarcely more than rudimentary till they are fully adult, and even then the horns are quite insignificant. In both sexes the horn is hollow, like that of the goat and the ox, and it is deciduous, like the antlers of the deer. Altogether this is a most interesting animal, occupying an intermediate place between ruminants with hollow and persistent horns, and those with solid and persistent ones. In skin and coat it is like the deer. Its eye is most like that of some of the antelopes. Its glandular system is most like that of the goat. In salaciousness it even excels the goat.

**Process for Condensing Beer.**—The process for condensing beer was recently explained by Dr. Bartlett, in a paper read before the London Society of Arts. Essentially it is the same as the process for condensing milk; the only difference between the two consists in the provision made, in beer-condensing, to save the alcohol. The apparatus employed consists of a copper vacuum-pan, with which is connected a condensing-worm. Two copper globes are attached for collecting the alcohol. A certain quantity of beer being pumped into the pan, a vacuum of twenty-five or twenty-six inches pressure is maintained, and a temperature of 130°–160° Fahr. during the first stage of the process. In a short space of time all of the alcohol flows into the lower globe, the connection between which and the upper is then closed. Thus the alcohol is collected without breaking the vacuum. This alcohol contains all the delicate flavors of the beer. The alcohol having been removed, the removal of water goes on till the beer is reduced to a semifluid state. In this way thirty-six gallons of beer is concentrated into a bulk of little over two gallons, and besides there is a little over two gallons of proof-alcohol.

When the condensed extract is taken from the vacuum pan and cooled, the alcohol is mixed with it. All the aromas and volatile matters that went over with the alcohol are thus returned to the extract. Every valuable constituent of the original beer is there present, *minus* only nine-tenths of the water. When it is desired to remake the beer, all that is required is to empty one of the tin cans of condensed beer, and make it up to the thirty-six gallons by the addition of water. The product is "flat," but carbonic-acid gas can be reproduced in it to any extent that may be desired by the addition of a little yeast or uncondensed beer. The total expense of condensing beer does not exceed the sum of fifty cents per barrel, and that of remaking about twice that sum.

**Damming of Streams by Drift-Ice.**—In the *American Journal of Science and Art* for March, Prof. J. D. Dana remarks upon certain phenomena attending the spring overflows of Connecticut rivers, and in these finds reasons for believing that, during the breaking up of the long glacial winter, the gaps, gorges, or narrows, along the river-courses, would have been liable to obstruction by floating ice. Such obstruction, he says, would have been of all grades, from that which could simply impede the free flow of the waters, to the nearly perfect dam. In particular cases the obstructions might have existed during a very long time, instead of for a few weeks, as happens after a modern winter. Again, the slackened or suspended flow of the water, caused by such ice-obstructions, would have favored the deposition and accumulation about them of drift, and some may have thus been converted into complete dams. This process might occasionally have wholly filled with earthy material a gorge or narrow valley—as in the Niagara River—so as to block up and divert the course of the stream.

In view of these probable conditions of the river-valleys during the glacial flood, the question arises whether the height of the upper terraces *above the narrows*, on the rivers of Connecticut, was not partly owing to the existence of ice-obstructions. That this was so seems highly probable; and the height of modern spring-floods in the Connecticut at Middletown and Hartford is now often due, in part, to this very cause. If such obstructions existed in the Thames, Connecticut, and Housatonic Valleys, they were only partial obstructions, for in the case of each the terrace of the valley below the narrows *declines quite gradually in height* from the level above the narrows, instead of abruptly. Moreover, the material of the terraces below the narrows is like that above. Further evidence of the existence of such ice-barriers is to be looked for in a distribution of gravel and large bowlders across the valley just above the narrows, where the ice-masses had been brought to a stop and piled up. Prof. Dana has as yet observed no satisfactory evidence of this kind, but thinks the question needs more investigation.

**Where the Army-Worm Moth lays its Eggs.**—The mode of oviposition in *Leucania unipuncta* (the army-worm moth) was, till the other day, an unsolved problem in entomology. During the current year Prof. C. V. Riley, State Entomologist of Missouri, undertook the methodical investigation of this subject, and at the meeting of the St. Louis Academy of Science, on May 1st, was able to announce that his researches had been entirely successful. Guided by the structure of the ovipositor, Mr. Riley concluded that the moth would naturally secrete the eggs where they could not be easily seen. This conclusion was afterward verified by direct observation, the author having witnessed the mode of oviposition on blue grass. The eggs are, as he surmised, secreted, being either glued in rows of from five to twenty in the groove which is formed by the folding of the terminal grass-blade, or else between the sheath and the stalk. The eggs are white, slightly iridescent, spherical, .02 inch in diameter. They are fastened to each other and to the leaf, and covered along the exposed portion by a white, glistening, viscid substance. As they mature the color becomes yellowish, and by the seventh day the brown head of the embryo shows distinctly through the shell. The larva emerges from the eighth to the tenth day, is 1.7 millimetre in length, dull, translucent white in color, with a large black-brown head, and is a looper, the two front pairs of abdominal prolegs being atrophied. On account of its extremely small size and of the color resembling the pale bases of the grass-stalks near the ground, it is almost impossible to find them even where they are numerous. The one great economical result of these researches is the indicating of an effectual mode of destroying the army-worm—viz., burning the eggs with the stubble.

**How the Mississippi wears away its Banks.**—The observation is made by Reclus, in his work "The Earth," that the Mississippi River seems to contradict the law of displacement of running water, which in consequence of the motion of the earth on its axis causes all streams which flow north or south to hug the west side of their valleys. But Mr. G. W. R. Bailey, in a paper published in the *Journal of the American Society of Civil Engineers*, shows that the anomaly is an apparent one only. "The river," he writes, "does wear away its western shoreline more rapidly than the eastern, but it cannot do otherwise than gradually excavate circular bends, of from twenty to twenty-five miles in circumference generally, and then cut them off, leaving them to the westward. There has been, always, an excess of overflow and of sedimentary deposits west, and by far the largest number, as well as the greatest bends when cut off, have been left to the west. The western portion of the valley is everywhere well filled with alluvion, and the swamps west have firm bottoms throughout the valley. Below Baton Rouge, where the river tends to the southeast, the swamps on the east are boggy and not well filled with deposits, and the large spaces covered by Lakes Maurepas and Pontchartrain are left unfilled.

"If the Mississippi had been a river of clear water (instead of being sedimentary), traversing a valley not alluvial, it would probably occupy the western side of its valley like other streams flowing toward the equator; but, as it is, it levees or embanks itself to the eastward by an excess of deposits west. It hugs the bluffs on the east side, down to the last one at Baton Rouge, for the reason that it could not be forced any farther eastward; but immediately below the last bluff, the excess of deposits west crowded the river-channel eastward still farther; the general direction thence to the present mouth being southeast. The mouth of the river having now reached very deep water in the Gulf of Mexico, and having advanced a little beyond the filling up of the gulf west, and beyond the southern limit of the western highlands, the tendency is to flow westward by the Southwest Pass, which is now the largest channel, conveying about one-third of the whole river to the sea."

**Glacial Phenomena.**—Prof. A. R. Grote recently delivered a lecture on "The Ice Age" before the Catholic Institute of Buffalo. He first called attention to the evidences of glacial action in the limestone rock underlying the surface deposit of sand, gravel, and clay, in that region. Another evidence of glacial action is the presence of erratic blocks; these too are found in the vicinity of Buffalo. In Europe the largest of these erratic blocks have been traced to their original site. Near Zürich, in Switzerland, there is a block estimated to weigh nearly 5,000 tons. Another block, of nearly equal weight, may be seen at Neufchâtel. By comparing their grain, structure, and form, it has been ascertained that they came from the Alps, and indeed the very ledge of rock of which they were once a part has been determined. To reach their present location they must have traversed what are now bodies of water, as the Lake of Geneva. Such blocks, of all sizes, being held fast in the ice at the bottom of the glacier, act as chisels on the rock beneath, producing scratches. And, as a river accumulates piles of sticks and rubbish along its banks, so does the glacier accumulate piles of stones and clay, known as *moraines*. *Medial* moraines are found where two glacial streams unite, just as a sand-bar marks the junction of two rivers. These medial moraines are extensions of *lateral* moraines which are found at the sides of the glacier. *Terminal* moraines are found at its mouth. Over the south-western portion of the State of New York, bowlders have been found which have come from the Lake Superior region, some of them containing copper-ore. Bowlders of transportation have also been found on the summit of Mount Washington, which is more than 6,200 feet high, showing that the glacier must have at one time overtopped this summit. The direction of the scratches shows that the general course of the ice-mass was from north to south. There was a glacier of the Connecticut, the Hudson, and the Alleghany Valleys. The ice occupied the place of the water-courses, and underneath it streams flowed to the sea.

**Lieutenant Cameron's Explorations.**—Lieutenant Cameron has returned safely to England from his memorable journey of exploration in Central Africa. He explored the head-waters of the Congo, an immense river-system, one of the feeders of which is the Lualaba, which drains Lake Tangauyika into the Congo, and which Livingstone supposed to be a tributary of the Nile. The Congo and its tributaries constitute one of the grandest systems of internal water-communication in the world. As to the wealth of the newly-explored country, Cameron describes it as enormous. From its mineral resources and agricultural capabilities it seems destined to become one of the granaries of the world, a centre of civilization, and the scene of iron manufactures when other parts of the world have been exhausted.

**Antiseptic Properties of Thymol.**—The following notes of experiments made by L. Lewin to determine the antiseptic and anti-fermentative properties of thymol we translate from *Gaea*. This substance, thymol, obtained by distillation from oil of thyme, occurs in white, highly-aromatic crystals; when dissolved in hot water in the proportion of one part per 1,000 it forms a fully-saturated solution possessing a neutral reaction. More concentrated watery solutions cannot be obtained, for, when dissolved in greater proportions than one in 1,000, the thymol evaporates. Lewin finds that 0.1 per cent. of this solution is sufficient to prevent fermentation in sugary liquids, no matter what the proportion of sugar and yeast. Milk to which a small quantity of the thymol solution was added did not begin to show signs of coagulation till twenty days later than milk with which an equal quantity of water had been mixed. Filtered white of egg in contact with the air was found to grow putrid in three or four days, whereas white of egg with which thymol-water had been mixed gave not the slightest indication of putridity after eleven weeks. The same results were obtained in treating pus with water and thymol: pus so treated at once lost its putrid odor, and continued to be odorless for five weeks, or until it had become dry.

**The English Commission on Vivisection.**—The Royal Commission appointed in England to inquire into the subject of experimentation on living animals, for scientific purposes, have reported unanimously against the absolute prohibition of this practice. "Our conclusion is," says the report, "that it is impossible altogether to prevent the practice of making experiments upon living animals for the attainment of knowledge applicable to the mitigation of human suffering or the prolongation of human life; that the attempt to do so could only be followed by the evasion of the law, or the flight of medical and physiological students from the United Kingdom to foreign schools and laboratories, and would, therefore, certainly result in no change favorable to the animals; that absolute prevention, even if it were possible, would not be reasonable; that the greatest mitigations of human suffering have been in part derived from such experiments; that by the use of anæsthetics in humane and skillful hands the pain which would otherwise be inflicted may, in the great majority of cases, be altogether prevented, and in the remaining cases greatly mitigated; that the infliction of severe and protracted agony is in any case to be avoided; that the abuse of the practice by inhuman or unskillful persons—in short, the infliction upon animals of any unnecessary pain—is justly abhorrent to the moral sense of Englishmen generally, not least so of the most distinguished physiologists and the most eminent surgeons and physicians; and that the support of these eminent persons, as well as of the general public, may be confidently expected for any reasonable measures intended to prevent abuse."

**Perception of Musical Tones.**—From the researches of Prof. Preyer, of Jena, on the "Limits of Perception of Musical Tones," it appears that the minimum limit for the normal ear is from sixteen to twenty-four vibrations per minute, and the maximum forty-one thousand vibrations, though persons with average powers of hearing were found to be absolutely deaf to tones of sixteen thousand, twelve thousand, or even fewer vibrations. Silence, according to Preyer, is a state of uniform minimum excitation of the auditory nerve-fibres. Silence is to the ear precisely what black is to the eye. The pressure of the fluid contents of the labyrinth and the flow of blood through the vessels must give rise to sensations of which we are unconscious only because of their uniformity, their constancy, and their low degree of intensity. Silence, when the attention is concentrated on the sense of hearing, is found to vary in degree just as the blackness of the visual field, when light is excluded from the eye, has been observed to vary. Lastly, the parallel between the auditory sense and the visual is borne out by a study of the entotic (intra-aural) sensations, which are closely analogous to well-known entoptical (or intra-ocular) phenomena.

**Dr. Mohr on the Source and Composition of Meteorites.**—From an examination of a large number of meteorites, Dr. Mohr, in Liebig's *Annalen der Chemie*, concludes that these bodies must have been formed upon a planet warmed by the sun, or by a sun in absolute rest, and in the lapse of an enormous length of time. Under what circumstances this planet has been shivered into fragments does not appear. It must have had a large collection of waters, a sea, which has likewise been dispersed, and which now is to be found in meteoric swarms, and in comets. The peculiarity of meteorites, as compared with our globe, consists, he says, in the circumstance that we find in the former more products of reduction, and, except the earths, no perfect oxides. Thus, in meteorites we find no ferric oxide, but metallic iron, sulphide of iron, and phosphide of nickel-iron. Upon our globe phosphorus occurs only as phosphoric acid. Hence the hypothetical planet where the meteorites originated must have been smaller than our globe, and have had a less dense atmosphere containing less free oxygen. The specific gravity of most meteorites agrees with the calculated density of the planetoids between Mars and Jupiter.

**A Sound-producing Spider.**—In the "Proceedings" of the Bengal Asiatic Society is given an account of a gigantic stridulating spider, from Assam. The sound-producing apparatus of this spider (a species of *Mygale*) consists of a *comb*, composed of a number of highly-elastic chitinous rods, situated on the inner face of the so-called maxillæ, and of a *scraper*, formed of an irregular row of sharp spines on the outer surface of the antennal claws. This apparatus is equally well developed in both sexes, as in most coleopterous insects, and is not confined to the males, as in the *Orthoptera*, *Homoptera*, and the stridulating spiders (*Theridion*), observed by Westring, in all of which the exclusive purpose of the sounds seems to be to charm or call the opposite sex.

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## NOTES.

The Royal Society of London has received from Mr. Phillips Jodrell £6,000 to be applied, principal as well as interest, to the encouragement of original research in the physical sciences. Mr. Jodrell's object in making this gift is to ascertain, by practical experiment, to what extent the progress of original research is retarded in England by the want of public support, and in what form an increased measure of support would be most likely to promote its development.

Chlorine was first employed industrially by Robert Hall, at White's bleach-works, near Nottingham. He procured from Germany a vial of chlorine-water, but the first experiment was not successful. The solution, being too strong, destroyed the fabric, but by degrees the new agent became manageable. The use of lime by Tennant, of Glasgow, in 1798, as an absorbent of chlorine, seems to have over-shadowed these early results.

In the *Tribune* mention is made of a paper recently read before the French Academy of Inscriptions, upon the determination of the age of the third pyramid at Ghizeh. It appears that M. Chabas, an Egyptologist, has succeeded in deciphering in the Ebers papyrus a certain hieroglyph, which he finds to represent the name of Menkeres, the builder of that pyramid. An astronomical note in the manuscript states that the heliacal rising of Sothis (the star Sirius) occurred in the ninth year of the reign of Menkeres. The astronomer Biot now made calculations to fix the time of this heliacal rising of Sirius, and found that it must have taken place between the years 3010 and 3007 B. C.

Dr. W. B. Richardson attributes the high vitality of Jews, as shown in statistics, to their strict observance of certain sanitary laws respecting diet, cleanliness, and abstinence from strong drink.

A Tasmanian correspondent of *Nature* relates an instance of extraordinary tenacity of life exhibited by an eel. Seven years ago an eel, which had been slightly injured, was placed along with other eels in a tank from which they were taken as required. This tank was fitted with finely-perforated zinc at each end, through which nothing but the most minute organisms could pass; otherwise it was perfectly tight. The injured eel was left after the others had been taken out, and so on again and again, when other lots were put in and removed. "It is still in the tank, perfectly transparent, and quite white, and is to all appearance healthy and lively enough."

Died, March 2, 1876, in Washington, at the early age of twenty-eight years, Archibald R. Marvine. In an obituary notice, published in the *American Journal of Science and Arts*, it is stated that Mr. Marvine graduated in 1870 from the Hooper Mining School, Harvard University; the same year he accompanied the Santo Domingo Expedition as assistant geologist; in 1871 he served as astronomer to the Wheeler Expedition, at the same time doing work as a geologist; in 1873 he was appointed geologist of the Hayden Survey Expedition. The hardships and privations he endured in the wilderness of Colorado undermined his health, and since the early winter of 1874–'75 he had been incapacitated for field-work.

The decrease in the number of small-pox cases in the Punjab, since the introduction of vaccination, is very striking. In 1869 there were 53,195 deaths; in 1871, 25,534; in 1874, 12,026. That this decrease is due to vaccination is shown from the fact that in the northern districts, where vaccination is in greater favor with the people than in the southern, the rate of small-pox mortality per 1,000 is 1.31, while in Umballa and six other southern districts the rate is 2.05.

The scientific results of the Polaris Expedition are nearly ready for publication. They will form four volumes, the first three of which, edited by Dr. Emil Bessels, will be devoted to hydrography, meteorology, and astronomy. The fourth volume, of which Admiral Davis has charge, will contain a narrative of the expedition and much biographical information.

A new industry has been introduced in France—the breeding of ants for their eggs. These eggs are sold to the breeders of pheasants. As yet the business is in the hands of its originator, a woman, and she already appears to be on the high-road to fortune.

From experiments made by Scolosuboff, it appears that dogs can absorb with impunity about sixteen times as much arsenic (in proportion to their weight) as would kill a human being.

The cinchona-tree has been introduced successfully into the island of Réunion. The cinchona-seeds were first sowed near the coast, and the young trees which grew from them were subsequently conveyed to an altitude of from 2,000 to 2,500 feet. There they thrive so well that in four years' time some of them grew to the height of twenty-one feet.

In the annual report of Prof. Henry it is stated that the Smithsonian Institution fund now amounts to $717,000. It is contemplated to authorize a series of experiments to determine accurately the rate of increase of the earth's temperature at progressive depths. Another project embraces new and careful experiments on the velocity of light. The work of ascertaining the weight of the earth by Cavendish's method will also probably be undertaken anew.

In the milk of cows affected by the foot and mouth disease, there is a marked tendency of the fat-globules to aggregate. The latter are also much larger than in healthy milk, and in advanced stages of the disease rise to the surface, not as cream, but as pure butter-fat. The film enveloping the particles of fat presents a glairy, mucus-like appearance, and is intensely refractive. It is only necessary to agitate a strongly-affected sample of the milk for a few minutes in order to obtain from a pint of milk a lump of butter weighing an ounce or more.

German manufacturers are purchasing the fish-bones gathered along the Norwegian coast at the great fish-curing stations. The bones make a good fertilizer, and when pulverized by suitable machinery at the point of collection are readily transported. It is estimated that the bone-product of the establishments in Newfoundland amount to 20,000,000 pounds a year.

Dr. R. Angus Smith advocates the culture of peat as a fuel. In the Grampian Hills he finds a bog, the annual product of which is ten tons of dry peat—equal to four tons of coal. By proper treatment it is possible to grow the material much faster than this. Indeed, the product of the bog mentioned above is considered to be far below the average.

Explosions of fire-damp in coal-mines are found to occur most numerously in times of low atmospheric pressure. When the pressure is great, the carburetted hydrogen is prevented from issuing from the walls and sides of the coal-seam; but when the pressure is suddenly lessened the gas escapes, and accumulates until sometimes it reaches the proportion sufficient with common air to form an explosive mixture.

Mr. Henry S. Drinker, of Philadelphia, mining engineer, is preparing a work on "American Tunnels and Tunneling," and has sent out a circular in which he requests that data concerning railroad tunnels, mining tunnels, headings, and drifts, be forwarded to him, so as to make the work as complete as possible. Mr. Drinker's address is 1,906 Pine Street, Philadelphia.

Applying to the elephant Flourens's mode of estimating the natural duration of an animal's life, viz., multiplying by five the number of years requisite to perfect its growth and development, Sir J. Emerson Tennent fixes the term of life for that great pachyderm at (thirty by five) a hundred and fifty years. Maturity is shown by the consolidation of the bones of the animal with the epiphyses, and in the elephant this consolidation is complete at the age of about thirty.

In the seal-fishery an enormous amount of wholesome meat is annually wasted. Only the blubber and skins of the seals are brought away. It is proposed to have the meat put up in tin cans at Disco, and so shipped to Europe for food.

A movement is on foot to bring about a uniformity of measures, instruments, and methods of observation, among physicians in all countries. It is proposed to ask the next International Medical Congress to constitute national commissions for the purpose of deciding upon the most practical means of attaining this object.

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# VOICE IN MAN AND IN ANIMALS.[1]

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## I.

MAN possesses language, and makes large use of it, while, on the other hand, not even the most intelligent animals have the power of designating objects, or of translating sensations into articulate speech. In this respect the distinction between man and beast is very marked. It has at all times been cited as an evidence of man's exceptional place in Nature. The physiologist, however, discovers an articulate voice in many animals. Some mammals give utterance to vowels and consonants, but the result is only one syllable repeated without variation. Birds, better gifted than the mammals, can sing, and also possess a brief vocabulary: the goldfinch pronounces several words, which it repeats again and again in moments of pleasure. It has a word to express its ill-humor, as also a word for calling attention. In all this we see faint traces of language, notable witnesses of the unity of a phenomenon the gradations of which are wanting.

Some animals live in society, others travel in flocks. In such aggregations there is plainly developed a sort of language adapted for establishing concert of action among the individuals. In building their lodges, how could beavers make a regular division of labor, and so perfectly coördinate their work, if they were unable to understand one another? The marmot, acting as a sentinel, could not warn its fellows of the approach of danger, if it did not possess the power of giving a signal, the meaning of which they understood. When swallows are about to migrate, some of them appear to be concerned about the performance of the periodical voyage some time before the rest: they flock together and utter their call; they flit hither and

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[1] Translated from the French by J. Fitzgerald, A. M.

thither to summon individuals who, in their folly, take no note of the change of temperature. Is it not plain that these birds know how to say, "It is time to be gone?"

But in all probability the language of animals gives expression only to very simple impressions and ideas. But, inasmuch as we do not understand it, we cannot define either its extent or its true character. Some persons have the power of imitating the calls and songs of birds; and birds, in turn, repeat human language, without, however, understanding its sense; it is only very rarely that we can recognize in the phrase uttered by the inhabitant of a cage the expression of a desire. Man and dog, close friends though they are, understand one another only by means of a sort of pantomime. Eventually the dog understands some of the words spoken by his master, and the man understands some of the vocal expressions of his trusty friend; and this is the highest result of long association. It appears as though, by a supreme will, an insurmountable obstacle had been opposed to all close communication between man and animals.

Apparently those animals whose organization comes nearest to that of man lack both the faculty of producing an *ensemble* of articulate sounds and the degree of intelligence requisite for attaching to words a strictly determinate meaning. No monkey has ever learned to talk. In our own day the comparative study of specialties of organization and of the life-conditions of living beings has thrown light upon the subject of articulate speech. We may confidently affirm that a creature possessing an instrument or an organ subject to the control of its will comes into the world possessed of an instinct to employ that organ or instrument; guided by intelligence, it will make more or less happy use of it. As individuals differ from one another in the perfection of their vocal organs, so too they differ in the measure of their control of those organs. Natural gifts and judicious exercise afford immense advantages. All men possess a vocal apparatus: for talking or for singing they usually employ it skillfully enough to answer all common demands; while a privileged few produce wonderful effects with the same instrumentalities.

The mechanism of voice deserves to be studied by all. As regards man, we now have very accurate knowledge of the manner in which speech and singing are produced. Means having been found of viewing the play of the different parts of the larynx, physicians intent upon the advancement of the art of healing, physiologists spurred on by the desire of explaining phenomena, singers eager to penetrate the secret of the highest achievements in their art, have all devoted themselves to patient researches. The results of a multitude of investigations have been published, and in this way science has been greatly extended. Dr. Mandl, an observer who had already studied in its minutest details the structure of the respiratory organs, has given the fullest account yet presented of the vocal apparatus in all the phases of its activity.[1] At present he is engaged in studying the phenomena of voice in the larger animals. As for birds, it is to be hoped that soon we shall understand the organic peculiarities in virtue of which they are able to talk or to sing. Doubtless before long we shall discover the relations subsisting between life-conditions, physical powers, and psychological faculties.

In all those communities which have attained a high degree of intellectual culture, the explanation of natural phenomena has ever more or less engaged the attention of the best minds. Among the ancients we observe a manful effort to discover the secret of the human organization. The origin of speech and of song was unquestionably a subject of profound inquiry for them. Galen, the last and the most famous of the ancient physicians, wrote a description of the larynx, and this description is the work of a master who recognizes the high importance of the work he is engaged in. Since the time of the Renaissance anatomists have been studying the minutest details, and physiologists experimenting. Thus everything was ready for new discoveries, so soon as it should be possible to place before the eye the performance of the instrument used by the singer. It would be difficult, without some knowledge of the vocal apparatus, to understand how the sounds are produced, and hence we will briefly describe those portions of the respiratory organs in which the voice is formed.

The trachea, which is the passage for air between the mouth and the lungs, ascends from the chest to the middle region of the neck; it is made up of cartilaginous rings. At its lower extremity it branches out into two tubes, which are divided and subdivided into numerous ramifications: these are the bronchi, which terminate in the lung-cells. At the upper extremity of the trachea is the larynx, appearing like an angular box, and crowning the trachea like the capital on a column. Cartilages connected by ligaments give considerable strength to the walls of the larynx. Internally these walls have a lining of mucous membrane, which forms folds known as the vocal cords, or better, lips. Under the action of special muscles these folds separate from one another, are elongated or shortened, or become tense, and hence the differences of sound. The cartilages are four in number: two on the anterior surface of the box and two on the sides. In advanced age these cartilaginous plates ossify; the suppleness of the larynx is then greatly diminished, and the voice loses the power of modulation which it possessed in the period of youth. One of the cartilages, which has the form of a ring, is much higher behind than in front. This ring, being firmly fixed upon the first ring of the trachea, serves to support the various parts which constitute the larynx. The largest of these parts shields, as it were, the front of the vocal apparatus: it consists of a plate of cartilage bent into a V-shape, with the point of

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[1] "Traité du Larynx et du Pharynx," 1872; "Hygiène de la Voix parlée et chantée," 1876.

the V turned forward. In women it is less prominent than in men, and it is known as Adam's apple. The lateral cartilages, which spring from the ring-cartilage at the back of the larynx, assume the form of little triangular pyramids with uneven surface. They are slightly curved toward the upper extremity, and support a little horny plate, which in the eyes of the ancient anatomists resembled the snout of a pitcher.[1] The lateral cartilages, being very mobile, play an important part in the emission of the voice.

The larynx is to some extent movable. Being attached to the hyoid or tongue bone by means of a membrane strengthened by ligaments, it is lifted up by the action of muscles extending from the tongue-bone to the external surface of the thyroid cartilage; it is pulled down by the action of muscles which extend from this same cartilage to the sternum. Further, the vocal apparatus is affected by the movements of the pharynx and of the tongue, as also by the respiratory movements. The solid parts of the larynx, being more or less movable, change position under the action of muscles which pass from one to another of them. Bundles of muscular fibre which spring from the annular cartilage (the cricoid) cause the thyroid cartilage to move up and down, and this movement produces tension of the vocal cords. Muscles springing from the cricoid and from the thyroid produce a rotation of the lateral cartilages, and modify the conditions of the cords. Finally, there are bundles of muscular fibre extending from one lateral cartilage to the other; when these contract, the walls of the larynx are brought nearer to each other, and the opening through which the air passes is made narrower.

Internally, the larynx is lined with mucous membrane, which is continuous with the mucous membrane of the mouth. Two pairs of ligaments, extending from the thyroid to the arytenoid, divide the cavity into compartments. The lower portion is limited by an arch formed of thick folds of mucous membrane. The middle portion is distinguished by the presence of folds supported by ligaments. These are the vocal cords, which play the principal part in the act of phonation. The superior cords, which resemble thin bands, occupy both sides. The inferior cords, or true vocal cords, which are very thick, are situated beneath the upper, and extend considerably beyond them toward the median line.[2] They bound the orifice called the glottis. This orifice, which in the state of repose is triangular in shape, varies constantly in form and in dimensions under the influence of respiration and the emission of the voice. This use of the term glottis, which signifies *tongue*, to designate an orifice, is very curious, and is

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[1] The ring-cartilage is the *cricoid* cartilage of the anatomists; the V-shaped cartilage is the *thyroid;* the lateral cartilages are the right and left *arytenoids;* and the little plate they bear, the *cartilages of Santorini.*

[2] On each side, between the superior and inferior vocal cords, occurs a large cavity. These cavities are known as Morgagni's ventricles.

the result of a strange confusion of ideas. The ancients observed in the larynx "organs resembling the mouth-pieces of ancient flutes, viz., the parts on the right and left, which meet and regulate the passage of the air." Later, the term denoting the folds which bound the orifice was used to designate the orifice itself. This error has been confirmed by the usage of centuries, but yet it is better to give, as Mandl does, to the space between the vocal lips, the name of glottic orifice, or orifice of the glottis. The superior portion of the larynx is the vestibule communicating directly with the back part of the mouth. Above the entrance to the vestibule and back of the tongue, a fibrocartilaginous plate, the epiglottis, defends the passage. Under ordinary circumstances, the epiglottis stands vertical, presenting no obstacle to the free passage of air in both directions. When depressed, it covers the opening. Every one, from personal experience, is familiar with the painful sensation produced by the entrance of liquids or solids into the respiratory passages. Apparently the epiglottis closes up this passage during the act of swallowing, but on this point we have no certainty; we cannot observe the act of deglutition, and we know that the vocal cords may be moistened by liquids without causing inconvenience.

Like every other organ, the larynx presents considerable individual differences. A good development of the larynx indicates a strong, deep voice. In childhood this apparatus undergoes very little change, but at the period of adolescence it grows very rapidly, the effect being an alteration of the voice, very notable in boys, but inconsiderable in girls. In all cases, without regard to stature, the larynx is smaller in women than in men. Its angles are less salient, its muscles weaker, its cartilages thinner, and more supple: the sharp notes of the instrument are the evidences of these peculiarities of conformation. Though our general knowledge of the vocal organs is very positive, nevertheless we are unable to determine the characters of the voice by simply examining the larynx, for it is impossible to compare in all their details those instruments whose good or bad qualities are known.

The vocal apparatus is perfected by the addition of the cavities which produce resonance, viz., the pharynx, the mouth, and the nasal fossæ. The pharyngeal cavity, into which open the œsophagus and the larynx, is continuous with the buccal cavity, a hollow box admirably adapted for articulation. Its shape and size are extremely variable. The cheeks constitute walls which can be compressed or dilated with the slightest effort; the lips, which bound the anterior opening, are perfectly mobile; the tongue can be moved in every direction; in the rear, the velum palati, or soft palate, suspended from the palatal arch, is supple and contractile. This veil of the palate is simply a fold of mucous membrane, separating the buccal from the pharyngeal cavity; it also extends to the nasal fossæ, which it closes; it terminates in an appendage called the uvula. When the velum palati, or soft palate, does not discharge its functions properly, the voice assumes a specially disagreeable character—it becomes nasal. The two rows of teeth act a part in producing speech; a breach once made in this rampart, the pronunciation becomes defective, the air escapes through the unguarded space, and the result is a hissing sound.

The plan of action of the whole vocal apparatus being under investigation, in the absence of the means of direct observation, recourse has been had to endless stratagems, in order to have a glimpse of the play of the organs and to explain the mechanism of voice-production. It has been a struggle with incredible difficulties, in which the human mind, though it has not won a complete victory, has nevertheless acquitted itself with honor. Some of the investigators succeeded in forming theories which are not very far from the truth, but these theories are now only the monuments of a period whose science is antiquated.

Galen, in comparing the organ of voice to a flute with double mouth-piece, referred the production of the sound to the vocal cords. Fabrizio d'Acquapendente, the famous professor of the University of Padua, held that the dilatation and contraction of the glottic orifice determined whether sounds shall be grave or acute. Dodart. a member of the old Académie des Sciences, held that the tone depends upon the greater or less number of vibrations of the vocal cords. Ferrein, one of the famous anatomists of the eighteenth century, conceived the idea of causing the larynx of a dead body to produce sounds by blowing through the trachea. He affirms that the lips of the glottis vibrate and emit sound like the strings of a violin. Magendie made experiments upon living animals; having laid bare the glottis, he saw the vocal cords vibrating when the animal uttered a cry. Savart, famed for his researches in acoustics, compared man's vocal apparatus to an organ-pipe. Lehfeld, a German author, laid stress upon the special effects of the cords, as vibrating through their entire substance, or only at their free edges. Cagniard de Latour constructed artificial larynges with mouth-pieces of membrane. John Müller, the physiologist, after a series of diversified researches, was of the opinion that "the vocal organ is a mouth-piece consisting of two lips, and that the vibrations of these is the chief cause of the sound—the pitch being determined by the width and length of the orifice of the glottis." Longet, who made numerous experiments on the actions of the muscles of the vocal organ, threw new light upon the conditions modifying the vibrations. In short, the result of all these researches, made by investigators who never had seen the larynx of a living man, was firmly to establish one point, namely, that the voice is formed in the glottis. The proofs of this are conclusive, for, if an opening be made in the trachea, the voice ceases; it reappears when we close the opening again; it persists though the superior parts of the larynx be rent and torn; but it is destroyed by lesion of the nerves of the little muscles which alter the form of the glottis and stretch the vocal cords.

But alongside of these undisputed facts there were a number of undecided questions which stimulated to further research. Some investigators were continually meditating on methods of viewing the larynx in normal action. Toward the close of the last century mirrors were first employed for this purpose, but the earliest attempts were unsuccessful. For fifty years all efforts of this kind proved abortive, and the thought of examining the interior of a living larynx was coming to be regarded as an illusion. Suddenly, as by an inspiration, the solution of the problem occurred to the mind of Manuel Garcia. Ignorant of the labors of others who had endeavored to obtain a view of the vocal apparatus, Garcia conceived the idea of observing his own vocal organs in the act of singing. Taking a small mirror attached to the end of a long rod, he placed it beneath the uvula, and then, illuminating with a beam of sunlight another mirror which he held in his hand, he had a full view of his own larynx. Thus was discovered the true method of investigation. In 1855 Garcia communicated to the London Royal Society the result of his observations on the living larynx.[1]

When a new mode of research is discovered, the first investigators to take hold of it are those who have little or no prepossessions of their own. They perceive that, by varying the application of the process, notable results may be attained without much labor or ability. Garcia's process called forth on many sides much enthusiastic zeal. This was the case especially at Vienna, but the results fell short of the anticipations. The caprices of the sun's light and the defects of artificial light were such as to discourage the observers. In order to succeed, the means of illumination had to be improved at any cost. Garcia had used for a reflector a plane mirror; J. Czermak, Professor of Physiology at Pesth, finding his pattern in the instrument used for inspecting the eye, the ophthalmoscope, employed a concave mirror, which concentrates the light. The feasibility of studying man's vocal apparatus by means of the laryngoscope was now insured. Still, for a long time afterward, experimenters busied themselves with devising contrivances for increasing the intensity of the light by combinations of glass lenses.[2]

Czermak, who by long practice had acquired great skill in the manipulation of his own larynx, visited the principal cities of Germany, taking with him a good instrument. His demonstrations were

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[1] "Observations on the Human Voice," "Proceedings of the Royal Society of London," vol. vii.

[2] The different kinds of instruments are described in Mandl's work, "Traité du Larynx;" also, in the article, "Laryngoscope," by Dr. Krishaber, in "Dictionnaire Encyclopédique des Sciences Médicales."

witnessed with profound interest by physicians and physiologists. In 1860 he came to Paris, and astonished many of the members of our learned societies. He exhibited not only the whole of his own larynx, but also the interior of his trachea down to the bifurcation—a sight well calculated to cause astonishment when one sees it for the first time. The vocal organ cannot be examined with the same facility in all persons, and some practice is needed for experimenting successfully. Dr. Mandl and Dr. Krishaber possess an extraordinary power of controlling the various movements of the larynx. After repeated experiments we now fully understand the functions of the vocal organs in speaking and in singing. The studies of Helmholtz upon the formation of sounds have thrown new light upon the phenomena of voice.

The notes of an organ, when heard beneath the arched roof of a cathedral, produce a profound impression. Inasmuch as no other kind of music so closely resembles the human voice, we can fancy ourselves communing with the thoughts and feelings of the human soul. We naturally compare the organ to man's vocal apparatus. The organ has a bellows, we have lungs; in the organ is a "sound-board," the trachea performs the same function; the vibrating tongue of the organ has its counterpart in our vocal cords; and the pharynx and the mouth answer to the resonating cavities of the organ. Yet the natural instrument is immensely superior to the artificial one. In the organ there must be a number of pipes to produce the different sounds; in the natural instrument there is only one pipe for both speech and song, but it is a wonderful pipe, being susceptible of endless modifications. It has a double vibrating spring and a resonator. The glottis is the vibrating spring or tongue, and, according as the air-passage is more or less narrowed, and the vocal cords more or less tense and vibrant, the sounds emitted are either grave or sharp. The mouth forms the resonator; the cavity of the mouth is susceptible of almost endless modifications, producing an infinite diversity of sounds.

Our various senses are each affected by a special order of impressions; the organ of hearing takes note of sounds, which are propagated by concussions of the air, by vibrations. When these vibrations are continuous, regular, isochronous, they constitute a musical sound; when irregular, the result is noise. Sounds possess very definite characters, as intensity, pitch, timbre. Intensity depends upon the amplitude of the vibrations, which travel in the form of concentric spheres from the starting-point, as the waves caused by a pebble dropped into water are diffused in the form of concentric circles. Amplitude is always the result of the force of the primary shock. The pitch of a sound is determined by the number of vibrations occurring in the space of one second: when the vibrations are few, the sound is grave; when very numerous, it is sharp. In a word, the shorter the duration of each vibration, the higher the pitch of the sound. Timbre means quality of voice. We distinguish voices by their timbre; we hear some one speaking, and recognize who it is without seeing him; or we hear a strain of music, with several sounds of the same pitch, but we readily by the timbre distinguish from one another the violin, the flute, the clarionet. The differences are the result of the different forms of the vibrations; this may be demonstrated by experiment. Whether we consider the movements of a pendulum or of a tuning-fork, in every case the vibration, when traced automatically, gives a characteristic line for each variety of timbre. If by means of the ear, rendered highly sensitive by long practice, we study to distinguish the different forms of the waves, we recognize in addition to the fundamental sound other higher sounds, the harmonics. Helmholtz's resonators aid the analysis by the ear. The resonator is a little hollow sphere with two open tubes, one of them conical, so as to fit into the auditory passage. The fundamental sound, which is much deeper than the other sounds, is thus considerably reënforced. In like manner, with the aid of proper resonators, it is easy to hear the harmonics of the human voice. Helmholtz ascribes the diversity of timbres to the intensity of the harmonics. Physiologists hold that there exist other causes, as yet not ascertainable.

In the state of rest, when respiration is performed without effort and with regularity, the vocal cords are almost motionless; during the alternations of inspiration and expiration, the orifice of the glottis does not alter its form. After a cry has been uttered, there occurs a deep inspiration, and then the vocal cords diverge, widening the aperture. When expiration is suspended or performed slowly, the orifice closes more or less. At the moment of emitting a sound, the lateral cartilages of the larynx are brought near to one another, and the vocal cords are suddenly made tense and applied closely to each other in their anterior portion, or even throughout their entire length; the passage of air is thus intercepted. Instantly the orifice opens again, and the air in passing between the vibrating vocal cords is itself thrown into vibrations, and sound is the result. These operations are performed gently or forcibly according to circumstances. Here we have the "glottic sound," as it is called by Mandl; isolated, it is inaudible, but it reaches our ear only after it has traversed the pharynx and the mouth; the vibrations of the air modify it. Every one has remarked the change produced in sounds by their passing through a tube or the like; for instance, when we hear a voice coming from the bottom of a well. Hence the voice is formed by the combination of the sounds of the glottis and of the cavities lying above the larynx: when these cavities are passive, the voice is inarticulate; when they undergo certain changes of form, the voice becomes articulate.

The pharynx and the mouth, which serve as a resonating box, produce sounds whenever the air they contain is made to vibrate by the current from the lungs or from any other source. That this is the case is shown by certain decisive and very interesting experiments. On opening the mouth and adjusting the lips for the pronunciation of a given vowel (though without uttering the slightest sound), the vowel may be rendered sonorous by placing in front of the mouth a vibrating tuning-fork. This method was first applied by Helmholtz. The same result may be obtained by bringing in front of the open mouth, through a tube with narrow terminal orifice, a current of air from a pair of bellows. This plan originated with M. König. Thus it is seen that the various sounds known as vowels depend simply on the form of the resonating cavities, the pharynx and the mouth.[1] When these cavities alone are in action, the voice is aphonic, whispering; it is sonorous when the vocal cords vibrate. For a long time it was held by physiologists that vowels pronounced even in a whisper come from the glottis; precise information concerning these phenomena is of very recent date.

The number of vowels is generally restricted to five, six, or seven; these may be regarded as natural types, being found in nearly all languages. But, in addition to them, there are intermediate vowels, and a multitude of vowel combinations, so great is the power of modification possessed by the buccal cavity. Then there are nasal intonations (very abundant in the French language) produced by depressing the velum palati. A language might consist only of vowels, says Max Müller, and indeed this is very nearly the case with some of the Polynesian dialects.

Most languages possess aspirates of more or less harshness. In French they are very few and weak, but in German they are frequent and strong, while in Arabic they are specially forcible. Aspiration requires the action of the glottis; the orifice is reduced for an instant, and the air, arrested by this obstacle, in issuing through the narrow slit, produces a sound of something brushing against the vocal cords. The aspirate is sometimes sonorous in the Semitic languages.[2] The guttural sounds of the Arabs used to be the subject of grave discussions among linguists, but Czermak put an end to these controversies. That learned physiologist, having fallen in with an Arab, availed himself of the opportunity to examine with the laryngoscope an organ capable of producing a sonorous aspirate. The whole matter was now plain: it was found that, while the epiglottis was depressed, the vocal cords were in close contact; the orifice being thus absolutely closed, the current of air driven against the roof produces a vibration beneath the glottis, in the fissure of the larynx.

The sounds produced in the buccal cavity are broken up on meet-

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[1] When we pronounce the vowels *a*, *e*, *i* (pronounced *ah*, *eh*, *ee*), the vertical diameter of the pharyngo-buccal cavity is diminished, while its transverse diameter is increased; it is exactly the contrary with the vowels *o*, *ou*, and *u* (pronounced *oh*, *oo*, *ü*).

[2] It is the *aïn* of the Arabic.

ing obstacles; thus are formed the sounds known as consonants. In setting up these obstacles, the tongue, the teeth, the lips, the soft palate, play respectively a more or less important part. We readily distinguish the labials, the linguals, the dentals, the nasals. No classification, however, will stand a rigid analysis; the simultaneous play of the teeth, tongue, lips, and soft palate, and the somewhat doubtful character of some sounds, render all classifications more or less arbitrary.

Among the consonants are the sounds of puffing, hissing, trilling, and these are pronounced without the aid of vowels.[1] The labials are formed mainly by the movement of the lips—the easiest movement of all those concerned in the utterance of speech. Accordingly as the lips are closed tightly or loosely, two distinct letters are pronounced; if the closure is imperfect, a third letter is produced.[2] There are two letters, *m* and *n*, which it is impossible to pronounce with the soft palate depressed, so as to close the nasal passages. Czermak introduced water into his nostrils, and then tried to pronounce these two consonants; the water was forced out by the passage of the air. The sound of the dentals is produced by a strong pressure of the tongue usually against the teeth, which, however, are not indispensable. The gutturals are pronounced by bringing the tongue back against the palate.

All these consonants may be classed, according to the character of the sound, as either *surds* or *explosives.* When the external air remains in communication with the air expired, notwithstanding the obstacle set up for articulation, the consonant may be sustained during the continuance of the expiration.[3] Where there is no communication, the duration of the sound is restricted to the instant in which the obstacle is removed, and the result is a slight explosion of the air.[4] This is shown conclusively when we precede a consonant with a vowel, and the same experiment serves clearly to show the distinction between hard and soft explosives.[5] In pronouncing the former the glottic orifice is narrow, the current of air is feeble, and the sound persists for a moment after the mouth has opened; in the other case, the glottis allows the passage of a stronger current of air, and the sound has no perceptible duration.

Certain consonants are in English called trills;[6] they are produced by the interruption of the breath at regular intervals, by vibrations of the soft palate and the extremity of the tongue. In the soft trill, the edges of the tongue produce simple oscillations of the air, but in the harsh trill, the vibrations produced at once by the palate and the tip of the tongue become intense. Finally, there are certain sounds of frequent occurrence in English, German, and the Slavonic languages; these are produced by an expiration differing from one

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[1] *f*, *s*, *r*.

[2] *b*, *p*, *v*.

[3] *z*, *zh*, *v*, *s*.

[4] *b*, *p*, *d*, *t*, *g* (hard), *k*, *x*.

[5] *b*, *d*, *gh*, as contrasted with *p*, *t*, *k*.

[6] *l* and *r*.

another according to the obstacles opposed by the tongue, the teeth, and the lips.[1]

It has been demonstrated that the sounds of speech are formed in the buccal cavity, by processes which vary within very narrow limits. Authors who have studied in their own persons the pronunciation of the vowels and consonants describe with great minuteness the positions assumed by the lips, the tongue, the soft palate, under all circumstances, and give drawings which show the various operations we perform while articulating letters and syllables.[2] These observations possess great interest; but yet the rules thence derived are not so rigorously true as to be indisputable. As Mandl observes, sounds that are nearly identical are produced with different positions of the organs of speech. If a person has lost all his teeth, he modifies the play of the lips and tongue, and so contrives to speak intelligibly. The voices of persons we know can be imitated so that the deception shall be perfect. By changing the timbre, the voice is made to sound as though it came from a cavern; this is the ventriloquist's art. Persons who had had the misfortune to lose a considerable portion of their tongue, have been able to converse, though it is not affirmed that hearing them speak would be a pleasure. Some birds find it possible to utter sounds which with us require the use of the lips. In a word, there is nothing absolute in the acts which produce speech, though in general the same organs do not differ very much in their mode of procuring the same results, as may be shown from the fact that congenital deaf-mutes who have learned to speak interpret the movements of the mouth with infallible certainty; they see the speech of the interlocutor. This proves that our modes of articulation present only shades of difference.

The phenomenon of deaf-mutes capable of speech has long been esteemed a marvel. In the middle ages there was one instance of this, the credit of which is due to the patience and skill of Beverley, Archbishop of York. In the sixteenth century, the universal scholar, Jerome Cardan, discussed the possibility of teaching the use of the voice to congenital mutes. About the same period, the Spanish monk Pedro de Ponce was, according to an epitaph, famous throughout the whole world for his power of causing mutes to speak. He had for his pupils two brothers and one sister of Pedro de Velasco, and the son of Gaspar de Guerra, Governor of Aragon. Some time later, Juan Pablo Bonet, in a work which is the oldest known upon this subject, treated of the art of giving speech to the dumb.[3] In

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[1] *sh* and *th* in English; *sch* in German; *tch* in Russian.

[2] *See* Ernst Brücke, "Grundzüge der Physiologie und Systematik der Sprachlaute für Linguisten und Taubstummenlehrer," Vienna, 1855; Max Müller, "Lectures on the Science of Language;" Johann Czermak, "Populäre physiologische Vorträge," Vienna, 1869, etc.

[3] "Abecedario demonstrativo: Reduccion de las letras y arte para enseñar a hablar los Mudos," 1620.

England, Holland, and Germany, this art was reduced to practice with more or less favorable results; instances of success were few and far between. About the year 1732, a young Israelite, who had come to France from Estremadura, being touched by the unhappy lot of a woman whom he loved, resolved to devote himself to the instruction of deaf-mutes. His name was Jacob Rodrigues Pereira. At La Rochelle, a boy thirteen years of age was brought to him; soon the lad was able to speak, so as to astonish all. The result was noised through the city; one of the *grands fermiers* had a deaf-mute son, whom Pereira undertook to instruct. After sixteen months of study, he presented his pupil to the Académie des Sciences. The assembly was delighted. Several of the members undertook to examine the case thoroughly, and on July 9, 1749, Buffon reported that the lad had answered questions "both in writing and by word of mouth." At the court of Louis XV. this marvel excited general admiration. The Duke de Chaulnes had a godson that was deaf, a boy of about twelve years; him he placed under the care of Pereira. This pupil, Saboureux de Fontenay, who in after-times attained to some celebrity, was very intelligent, and quickly improved under instruction. On being exhibited at the Académie des Sciences, and there tested in various exercises, he occasioned no little surprise. The official report concludes by stating that "M. Pereira possesses a singular gift of teaching congenital mutes to speak and read."

Pensioned by the king, and honored with marks of esteem by illustrious personages, Pereira continued his labors. He gave the power of speech to a large number of mutes, but he kept his method of education secret. The memory of this brilliant success had been wellnigh effaced, when the Abbé de l'Épée won the favor of all classes of society by giving to the deaf a sign-language. Pereira left behind him pupils who justly believed that they did honor to their master by making public the secret of their instruction; some of these scattered notes have been collected. It has required only a little research to discover the forgotten method.[1] The teaching of deaf-mutes to speak was again brought into practice, and at Geneva M. Magnat was very successful in carrying out this system. He visited Paris, accompanied by some of his pupils, who, though utterly deaf, conversed with wonderful ease. Some grandsons and great-grandsons of Jacob Rodrigues Pereira, on witnessing the renewal of the wonders performed by their ancestor, founded at Paris an institution for educating mutes. In this establishment, children of various ages, about thirty in number, afford matter for curious observations upon the phenomenon of voice and the articulation of language.[2]

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[1] *See* an interesting sketch by M. Félix Hément, entitled "Jacob Rodrigues Pereire, premier instituteur des sourds-muets en France," 1875.

[2] The institution founded by the Messrs. Pereire, at 94 Avenue Villars, Paris, is directed by M. Magnat, author of the "Cours d'articulation, pour l'enseignement de la parole articulée aux sourds-muets," 1874.

A person who is deaf from birth is also absolutely dumb, until he is trained to the use of speech; he utters no cry. His lips and tongue are motionless; his mouth remains shut, his larynx is in a state of unbroken repose; he breathes only through the nostrils. When first the effort is made to have him pronounce a letter written on the blackboard, it appears to be simply impossible for him to produce any sound. The instructor shows the young mute how to open the mouth, and how to hold the tongue and the lips. He places the child's hand upon his own larynx, so that it may feel the movement necessary to be performed. In the beginning, the simple expulsion of the breath is difficult, but, after repeated exercise, there is a sort of stifled articulation; later, with some difficulty, a clear sound is obtained. In this way the deaf-mute learns to pronounce all the vowels and consonants. It needs but a short time to acquire the pronunciation of the labials. Longer practice is needed in order to learn the play of the tongue, and the proper mode of emitting the breath in articulating those consonants which call for only a slight intervention of the lips. Having learned the alphabet, the mute begins to pronounce syllables and phrases written on the blackboard. Finally, he speaks, and is understood. He writes from dictation, with his eyes fixed upon the person who addresses him questions, and makes his answers confidently.

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# OUR COMMON MOULDS.

By BYRON D. HALSTEAD

THE following remarks are from personal observations which have been made from time to time as circumstances would permit. For convenience, the term *mould* will be extended beyond its narrow technical meaning, and include all those forms of vegetable life which are usually designated by that name. No lengthy argument is needed to prove that mould is of common occurrence. It is a fact well known to every person, from the wholesale provision-dealer down to the hungry child who eats his crust upon the street.

Where these plants do not grow it is difficult to say; but to point out the favorable conditions for their growth and some of the forms which they there assume is an easier task, and to this part of the subject the reader's attention is invited.

Moulds belong to that peculiar parasitic group of plants called *Fungi*, the members of which never have anything like green leaves, the workshops of higher plants, and are therefore unable to build up their tissue from unorganized matter. They must feed upon that which is already organized, either animal or vegetable, living or dead, as the species will decide.

One of the most essential conditions for the development of these minute fungi is the presence of a good degree of moisture. So well known is this, that to many minds *moisture* and *mould* bear to each other nothing less than the relation of cause and effect. A warm atmosphere is also required. In winter the housewife exercises fewer precautions to keep these intruders from her viands than during the warm summer weather. Besides organic matter, moisture, and warmth, a free access of oxygen must be added as an essential condition for the perfect development of moulds.

When the season comes and the soil is ready, the farmer knows he must sow the seed, or he cannot hope to reap a harvest. So it is with the moulds: to the conditions for growth there must be added the germs of life, or no mould will be produced. How this sowing is accomplished will be better seen after some of the species are considered more in detail.

Our common bread is a substance which offers special inducements for the growth of various moulds, and, in order to study them, a slice was taken and placed on a zinc rack on a dinner-plate and covered with a glass bell-jar lined with filtering-paper which dipped into some water in the bottom of the plate, producing thus a moist atmosphere by the evaporation from its extensive surface. This culture (Fig. 1), placed in a warm room, secured all the important conditions for the production of a crop of mould. On the bread thus situated a mould made its appearance in about thirty-six hours, and proved to be one of the most common of the bread-moulds (*Mucor stolonifer*), shown in Fig. 2. When first noticeable, the surface of the bread is covered with a cobweb-like mass of fine white threads, called *mycelium*, which run in all directions through the tissue of the bread, and perform the work of absorbing nourishment. Soon other and larger threads begin to rise into the air, their tips enlarge, the protoplasmic contents of the threads passing up into the ends, which finally assume a spherical shape. At first these large round heads are of a white

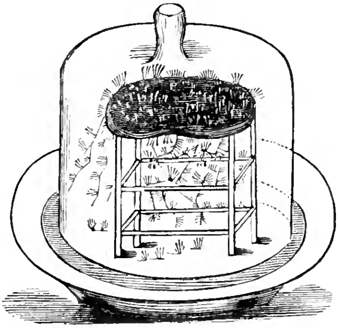

FIG. 1.—MOULD CULTURE.

color; but soon they begin to grow darker, their contents shaping into little round bodies, which when ripe are dark-colored and fill the capsule to repletion. These little bodies thus produced in vast numbers in the swollen ends of these vertical threads are termed *spores*, and answer the same purpose for moulds that seeds do for flowering plants. From the same base several of these capsules are produced, varying in age from threads with their tips little swollen, to the tall and aged ones which have ripened and scattered their spores. This mould has much the habit of the strawberry-plant, throwing out runners or stolons, which take root and in turn become new plants to increase and continue the species. In the culture we have often seen this mould hanging from the bread on the rack to the plate below, a distance of four or five inches, with here and there the stolons with their fruit-clusters hanging in mid-air (Fig. 1).

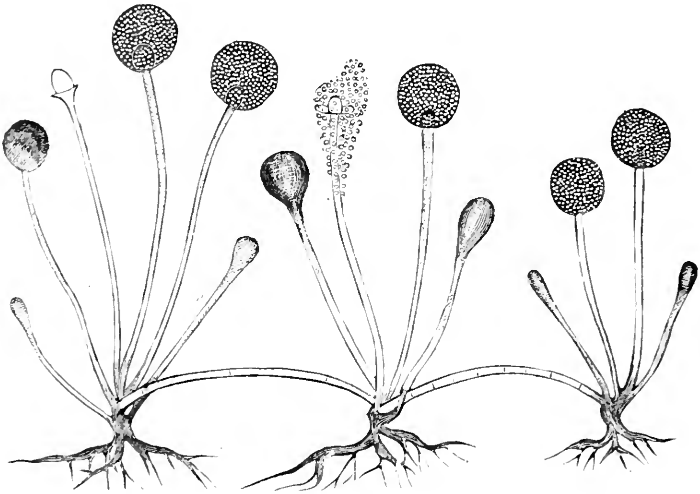

Fig. 2.

The fruiting which has been described is asexual, and the spores thus formed can be likened to the bulbs in the axils of the leaves of the tiger-lily and other reproductive bodies in flowering plants which do not result from a fertilized ovule. Several trials were made to cultivate the sexual fruit of this plant, but without success; another member of the same genus (*Mucor Syzygites*), which grows on decaying toadstools, produced them under the bell-jar in large quantities. When this plant reaches the proper stage of development for the formation of its sexual fruit, the tips of various filaments become noticeably swollen. Two of such enlarged ends grow toward each other and finally meet by their extremities, or rather by the blending of the processes which each cell puts out, thus forming at first a small cell between the two united filaments. As maturity is reached, this *zygaspore* acquires a diameter much greater than that of the filaments which have produced it, and is many hundred times the size of the spores formed in the capsules. It is also provided with two coats, the outer one thick, dark-colored, and covered with warty excrescences, except on the two ends where the remnants of the conjugated filaments remain. Successive stages in the development of these spores are shown in Fig. 3. At *a* the two swollen threads are near each other; *b*, the process partly completed, with the middle cell plainly seen; and *c*, the full-formed zygaspore, with the remains of the old cells. The importance of these sexual spores in the economy of the plant is not difficult to understand. The minute asexual spores have a very thin covering, and under favorable conditions will germinate as soon as formed, but on the other hand are readily destroyed by extreme climatic changes. The large, well-protected zygaspores which germinate only after months of ripening, are in every way fitted to carry the species through the unpropitious season of winter, times of drought, and severe exposure. When the zygaspore germinates it produces very soon a large crop of capsules, and their little spores are scattered far and wide ready to develop into plants in a few hours, as circumstances shall decide. This dual form of fruiting is an interesting feature in the life of these little plants, and is as effectual in preserving the species as it is interesting.

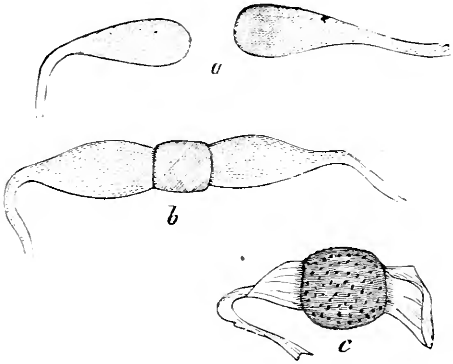

Fig. 3.—Zygospores of Mucor Syzygites. De Bary.

After upward of a week from the time the *Mucor*, of which we have been speaking, made its appearance on the bread, another mould was noticed growing over its surface, which was of a much finer structure and dingy yellow in color. When placed under the microscope, it was found to be peculiar, both in structure and habit of growth. The filament which bears the spores, as it rises from the matted surface of the *Mucor*, divides into two branches, each of these into two others, and so on, until ten or more branches are reached. The same angle of divergence being preserved in all the branching, the compound top assumes a very regular, semicircular outline, as shown in Fig. 4, *a*, where the filaments are represented by single lines; the whole of the branch *b* is a more highly-magnified view of a dark tip at the end of one of the branches in *a*; and at *c* is shown, on a still higher scale, one of the ultimate branches in *b*, with the spores arranged in rows of four around the enlarged end; while *d* is one of those tips after the spores have fallen away.

The reader will please bear in mind that this figure, and all the others, with the single exception of the first one, represent the object as greatly enlarged—the microscope used for most of the work magnifying 650 diameters. An entire plant of the one in question (*Piptocephalis Fresœniana*) is scarcely visible to the naked eye when prepared on a glass slide for investigation with the microscope.

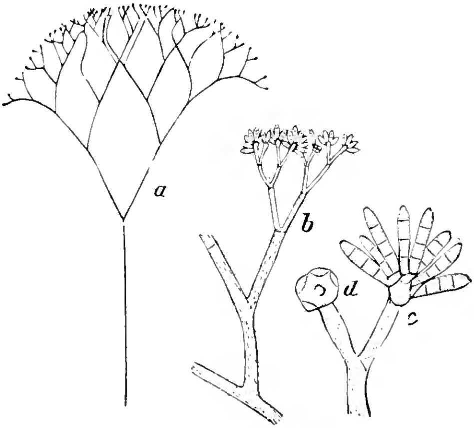

Fig. 4.—Piptocephalis Fresæniana. De Bary.

That which makes this mould of particular interest is the fact that it is a parasite, and cannot live unless it has some other mould upon which to grow. This easily explains why it does not make its appearance until the *Mucor* is well established. Here we have a true parasite growing on a saprophyte; or one mould which steals its substance from another which derives its living from the bread. We will not stop to reason upon the matter, or wonder how this strange state of things came about, but will leave the fact as it exists to those who would know the cause of all things both great and small.

There were two or three other members of the *Mucor* genus which grew on various cultures, but, as they differ only in minor points of structure from the one treated, space will not permit of their being further mentioned.

The bones of a recently-killed dog proved to be very well adapted for the growth of the largest-known species of mould. Those who have a passion for scientific names may call it *Phycomyces nitens*. It is one of the few moulds which grow on oil or oily substances, and is so filthy in its habits as to flourish in the sewers and cesspools of cities. It is so much like Fig. 2 in structure and manner of fruiting, though many times larger, that it must pass without an illustration.

The pulp of oranges is an especially favorable diet for some of the most delicate moulds. A culture made of it will show decided signs of mouldiness in twenty-four hours, and after thirty-six hours of growth there is a fine crop for study. Those which we have seen on the bread are invariably the first to appear here, though followed in a short time by others, one of the most common of which is given in Fig. 5. At the base *a* are some mycelial threads which penetrate the tissue of the pulp, and from them, as they come to the surface, arise the fruit-stalks which branch near the top into a loose head with the spore capsules borne on the ends of the branches. At *c* is one of the *Sporangia* more highly magnified, showing the spores to be larger and few in number as compared with the *Mucor*. This species is a member of the same family with those already mentioned, and has its similar zygaspores.

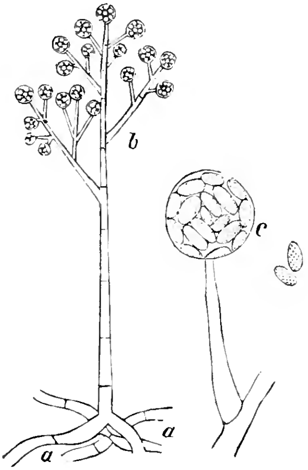

FIG. 5.

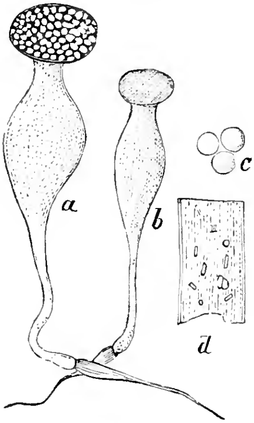

FIG. 6.

Corn-starch pudding, when placed in a bell-jar, remained unchanged until the fourth week, when its surface became coated with a peculiar yellow-colored substance, and a day or so after black specks began to appear. When viewed with the microscope, this mould exhibited the structure seen in Fig. 6. There arises from the unbranched and imbedded filaments a very much swollen end (*a* and *b*) filled with protoplasm, yellow globules of oil, and crystals (*d*). As this end increases in size, a contraction takes place near the upper end, and soon a distinct spore capsule is formed of the end thus separated. When the plant is ripe a black elastic coat covers the spore-case, which slips partly off when the spores are discharged from below. There are several species growing on various substances, which have the general structure of Fig. 6.

We now come to the most common of all the members of the group of moulds: the blue mould of cheese, bread, and almost every article of food. In its diet, it does not confine itself to those things found in a well-stocked pantry, but will flourish on old boots and other articles of clothing when they are left for a few days in a warm, damp place. No culture was made without its making its appearance, and often to the exclusion of all other forms. It is quite small, never reaching but a very short distance from the substance on which it grows, and under favorable circumstances forms an even blue crust over the surface of the nourishing material whether boots or bread. The structure of this frequent and often unexpected and unwelcome visitor is given in Fig. 7. Two fully-developed fruit-stalks are seen at *a* and *b*, branching irregularly at the top, and bearing the naked spores in chains at the ends of the filaments. At *c* is a young stalk before the spores have formed from the threads, which is done by a constriction, a familiar but perhaps rude illustration of which is seen in the making of the links of sausage. As the spores fall away, new ones are formed below, and so the process of producing these simplest of reproductive bodies is indefinitely continued. At the base *d* are the threads which penetrate the nourishing substance, on some of which are formed, as the result of sexual action, spherical bodies which inclose the more enduring sexual spores. From this method of forming subterranean fruit this little mould is a close relative to the truffle so highly prized for food.

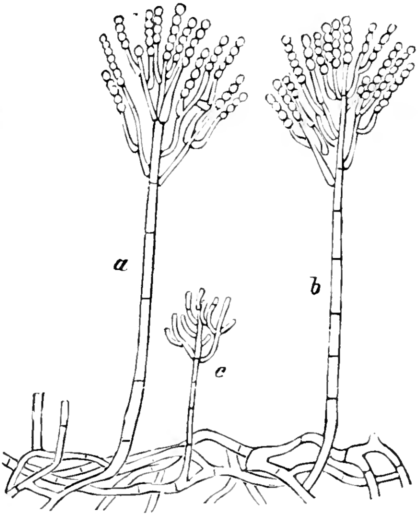

FIG. 7.—PENICILLIUM CRUSTACEUM. Fr.

With the spores of this mould repeated sowings have been made, with gratifying results. When a slice of fresh bread was placed in the bell-jar and certain marked places were sprinkled with spores by means of a pair of forceps, in the course of twenty-six hours those spots sown were covered with the young mould, while all other places were entirely free from it. In one case a fresh slice of bread was wrapped in a piece of paper, with the exception of a star-shaped figure cut from the paper, which came in the middle of the slice. Over the whole a slice of mouldy bread was shaken so gently that no spores were seen to fall; the paper was then carefully removed, and the bread placed under the bell-jar. After the usual time a fine star of blue mould made its appearance, soon spreading over the whole of the bread. One could as easily write his name in mould on bread as with clover-seed upon the soil, though it would not be as enduring an inscription.

It seems difficult for some people to see how the spores of these various moulds can exist almost everywhere, ready to grow when the first opportunity offers itself. With the hope of making this matter appear clearer, the following calculations have been carefully made: The blue mould (*Penicillium crustaceum*) is very favorable for the estimation of the number of spores produced, as the heads are quite open, and the spores are naked and distinct.

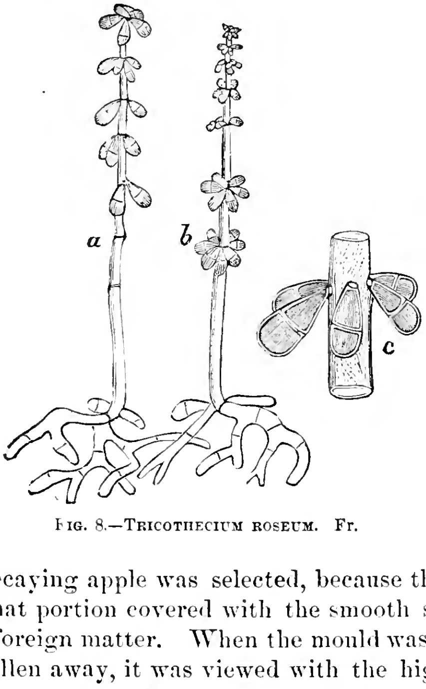

Fig. 8.—Tricothecium roseum. Fr.

A piece of decaying apple was selected, because the mould can be removed from that portion covered with the smooth skin without being mixed with foreign matter. When the mould was still young and no spores had fallen away, it was viewed with the high power of the microscope. There were usually twenty filaments to each head, and twenty spores on a filament, or 4,000 spores to a head or single stalk.

A small tuft was then carefully taken from the apple, and placed on a glass slide, and its area measured with the micrometer, and the number of fruit-stalks it contained determined. The surface was $\frac{1}{100}$ of an inch square, and the number of stalks 800. As the square inch is a familiar unit of measurement, the estimate made for that small extent of surface gives 3,200,000,000 spores. It is a well-known fact that not only inches, but feet, and even acres of this mould are produced, and the number of spores for daily use must be perfectly appalling. They are light, airy, and invisible to the naked eye and therefore ecape our notice; were they female mosquitoes, we would realize their nearness and number. With such multitudes of germs produced we need not wonder that the sowing for moulds should be natural and complete. The light which the microscope throws upon this subject makes it unnecessary to resort to "spontaneous generation" to account for the almost certain growth of mould when the proper conditions are combined.

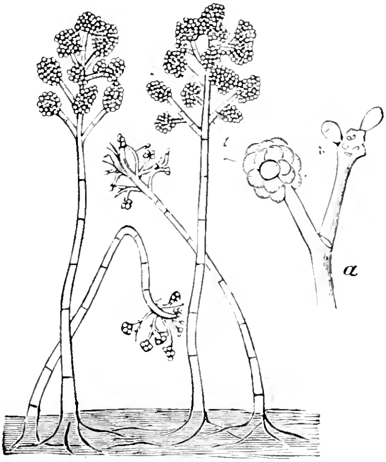

Fig. 9.—Peziza Fucheliana. De Bary.

When a slice of bread which has been thoroughly overrun by the *Penicillium* is left under the bell-jar, another mould almost invariably comes, covering the blue surface with a rose-colored coat. The asexual spores and their method of formation are given in Fig. 8. It will be observed that the fruit-stalks are unbranched, the spores when mature always double, and arranged on the stalks in whorls. The development is from below upward: *a* showing an old stalk with the youngest spores nearly ripe, and some of the older ones gone from their attachments; at *b* is a younger stalk, where the older whorls are complete and the upper ones small and indistinguishable; *c* is a more enlarged view of a cluster of ripe spores. After this mould, which is of slow growth, has run its course, the bread seldom produces any other forms, and for further study a new culture must be made.

In Fig. 9 is given a mould which makes its home on decaying herbage, and is found to perfection in old waste-heaps where weeds and other green matter have been deposited. So common is it, that a culture is more a matter of convenience than necessity. The fruit-stalks are upright, considerably branched at the top, with the spores borne in bunches at the ends of the filament. At *a* is a much enlarged view of one of these naked heads of spores, and another where the spores have mostly fallen away. As the fruit-stalks grow old they break down in every way, giving the appearance of a forest over which a tempest has passed.

Of the black moulds Fig. 10 shows a common and very simple representation. It grew as a sooty coating on a culture made of sliced raw potatoes. It is so very simple that any space taken for description seems unnecessary. The black spores are nothing more than portions of single or branched filaments cut off in a very regular manner.

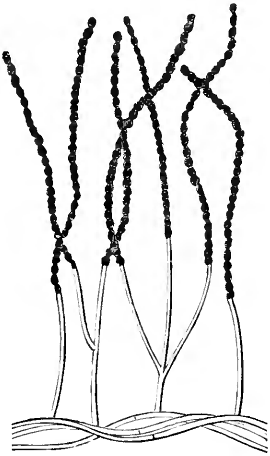

FIG. 10.

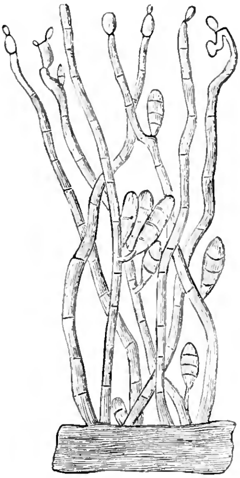

FIG 11.

In Fig. 11 is given the general structure of a large number of related moulds which grow wherever they can get a foothold. The drawing was made from one found on some turnip-roots left upon the ground over winter. Like many others, it forms an olive-brown, velvety coating of considerable thickness; and, because of their low habits and inobtrusive nature, they pass readily for dirt or decay, and are seldom noticed. They are the lowly forms which some of the highest of the fungi assume in passing through one stage of their polymorphic existence.

A score of other species of moulds deserve mention here which are found on various substances either forced under the bell-jar, or growing naturally; but we know how unattractive such descriptions would be without accompanying figures, and therefore pass them by.

For the last place in this brief enumeration we have reserved one of the most common of household moulds. It is the prince of moulds, and claims relationship with the most perfect and beautiful of fungi. In diet it is something of an epicure, and may well be called the cake and preserve mould,.and on those substances the best results are always obtained when used for its culture. Though preferring its cake and preserves, it was induced to grow on a tempting dish of stewed prunes, which afterward furnished the substance for its culture.

To the naked eye this mould at first appears as white patches; soon stalks rise from the surface, and on the end of each a small spherical head is borne, which increases in size and turns to a bluish color, so that when this mould is ripe the surface of the nourishing substance does not differ greatly in color from the *Penicillium* on the bread, though this mould is much taller and more inclined to grow in tufts. Under the microscope the tip of a very young filament which is to form a head of spores is seen to be perfectly smooth and similar to those in the *Mucor*, but very soon small peg-like projections begin to grow from its surface, which increase in size and finally divide, forming radiating rows of spores.

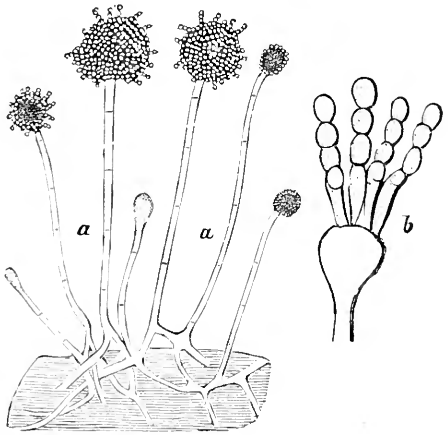

FIG. 12.—EUROTIUM ASPERGILLUS GLAUCUS. De Bary.

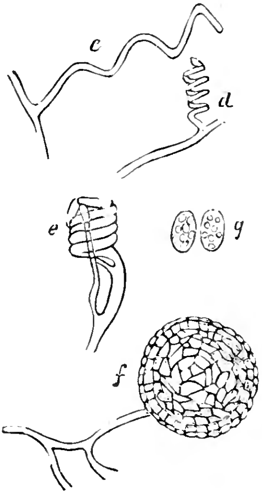

FIG. 13.

Various stages in the development of the asexual fruiting of this mould are shown in Fig. 12, *a*, *a*, with a view of an imaginary cross-section through one of these heads highly magnified in *b*, giving the method of attachment of the spore-threads.

Shortly after the heads have formed, the sexual fruit begins to develop on the mycelium at the base of the fruit-stalks. The method is more complicated than in any of the moulds already given, and places this plant among the most highly developed of fungi. The process begins with the coiling of the end of a thread in a corkscrew manner as seen in *c* and *d* (Fig. 13). The coils grow closer together as the filament increases in size, until a hollow cylinder is formed. From the same threads below the base of the coil one or more processes grow out which are the male organs, and, where one of these threads reaches the tip of the female coiled filament, that organ is fertilized. From this time on, this body undergoes various and complicated changes, which finally result in a bright-yellow spherical body (Fig. 13, *f*), which consists of a thin wall inclosing a large number of sacs, *g*, each of which contains eight spores.

To find all these various stages of development is a matter of some time and patience; but nothing is more satisfactory in the study of moulds than to trace all these steps, from the first bending of the filament to the perfect sphere with its multitude of spores.

For a long time these two forms of fruit in the *Aspergillus* were considered as belonging to distinct and widely-separated species, but, when the microscope shows that they are produced from the same mycelium, it is time to conclude that they are but two methods of continuing the same species.

Space forbids further details concerning our common moulds; but it is hoped enough has been said to show that among them the species are distinct. The tiny forests which the microscope reveals are made up of forms as decided as those which compose our woodlands and groves. In closing, the reader expects an answer to the question which very naturally arises, viz., "What good do they do?" Though often of great annoyance in domestic and other affairs, yet all in all it is safe to say the good they accomplish far overbalances the harm. They are scavengers which do in their own inobtrusive way a vast amount of sanitary work. Though small in themselves, they are great reducing agents, striving to bring about that equilibrium so necessary to perfect harmony in the organic world. They hasten decay, tear down the accumulating rubbish around us, and allow the elements thus liberated to pass again into the cycle of ceaseless activity and growth.

To the thoughtful mind moulds do not simply excite wonder or disgust, but teach a deeper lesson of adaptation and service of little things, in the perfect and economical scheme of creation.

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# WHAT ARE SPECIES?

By Prof. T. H. HUXLEY.

IN its most general acceptation the word "species" signifies a kind or sort of something, which something is the *genus* to which the species belongs. Thus, a black stone is a species of the genus stone; a gray horse is a species of the genus horse; a scalene triangle is a species of the genus triangle; and, generally, it may be said that every adjective denotes a species of the genus indicated by the substantive to which it is applied.

In the technology of the physical sciences the term "species" has a more restricted signification. It is used to denote a group of individuals which corresponds with an early stage of that process of abstraction by which the qualities of individual objects are arranged in the subordinated categories of classification.

The individual object alone exists in Nature; but, when individual objects are compared, it is found that many agree in all those characters which, for the particular purpose of the classifier, are regarded as important, while they differ only in those which are unimportant; and those which thus agree constitute a species, the definition of which is a statement of the common characters of the individuals which compose the species.

Again, when the species thus established are compared, certain of them are found to agree with one another, and to differ from all the rest in some one or more peculiarities. They thus form a group, which, logically, is merely a species of higher order, while technically it is termed a "genus." And, by a continuation of the same process, genera are grouped into families, families into orders, and so on. Each of the groups thus named is in the logical sense a genus, of which the next lower groups constitute the species.

The characters on which species are based necessarily depend upon the nature of the bodies classified. Thus, mineral species are founded upon purely morphological characters; that is to say, they are defined by peculiarities either of form, color, and the like, or of structure, which last term may be used to include both the physical and the chemical characteristics of a mineral. The distinction between a species and a variety is wholly arbitrary, except so far as it is commonly agreed that individuals which differ from others only as terms of a gradual series of modifications belong to the same species, and are to be considered merely as varieties of that species.

It is conceivable that animals and plants should have been known to us only by their remains preserved in museums or in the fossil state. If this had been the case, biological, like mineralogical species, could have been defined only by morphological characters; that is to say, by the peculiarities of their outward form and inward structure; and, as a matter of fact, this is the state of our knowledge in respect of a large proportion of the existing fauna and flora of the world, and of all extinct animals and plants.

A botanist or a conchologist who sets to work to arrange a newly-received collection sorts his plants or his shells out according to their likenesses and unlikenesses of form and structure, until he has arranged them into groups of individuals which agree in certain constant characters and differ only by insignificant features, or by such peculiarities as vary in different individuals in such a manner that an insensible gradation can be traced between those forms which have the peculiarity strongly marked and those in which it is absent.

Thus far the considerations which guide the biologist in the establishment of species differ in no respect from those which influence the mineralogist.

But although naturalists have no more direct knowledge of any but the morphological character of the great majority of the species of animals and plants than they would have of so many mineral specimens, they are familiar with many animals and plants in the living state when they exhibit phenomena to which the mineral world presents no parallel, and the study of these phenomena of active life has complicated the conception of species in biology, by adding physiological to morphological considerations.

The fact that living beings originate by generation from other living beings is one of the circumstances in their history which most completely differentiates them from minerals. This process of generation enters in various ways into the conception of biological species.

For example, it is a generally assumed axiom in biology that whatever proceeds from a living being by way of generation is of the same species as that from which it proceeds, whether the morphological differences between parent and offspring be great or small. The two sexes are often extraordinarily different, and in cases of the so-called alternation of generation the successive zoöids may differ very widely; but, inasmuch as the differing forms in these cases proceed from the same parents, no one doubts that they belong to the same species. The breeds of domesticated animals and plants often differ morphologically as widely as admitted species, but, apart from other considerations, historical evidence that they have the same parentage suffices to cause them to be regarded as of one species. It is not quite clear that the converse of the axiom which has just been referred to would be admitted, and that living beings which arise from totally distinct parents are of different species, even though morphologically identical. The wellnigh exploded hypothesis of the multiplicity of centres of origin for species of wide distribution implies the belief that groups of individuals which have proceeded from distinctly-created parents may, nevertheless, be of the same species, while the supporters of the no less nearly extinct hypothesis of the independent creation of the fauna and flora of successive formations used to affirm that, although indistinguishable, two forms from separate formations must be of distinct species, because they had been created separately. However, these subtilties have ceased to have any practical importance.

In the next place it is observed that, while individuals of the same morphological species breed freely with one another and give rise to perfectly fertile offspring, the unions of individuals of different morphological species are, as a rule, either unfertile or imperfectly fertile.

Thus fertility, like parentage, has become a physiological character of species; and, though in the case of some domesticated animals, as pigeons, the extreme forms are more different from one another than many morphological species, yet they, apart from the historical evidence of their parentage, are held to be members of the same species, because they are all perfectly fertile one with another, and their offspring are also perfectly fertile.

Thirdly, it is a matter of experience that, as a general rule, and taking the whole cycle of forms through which a living being runs into account, offspring and parent are so similar that they belong to one and the same morphological species; and it is further in evidence that many species have endured for extremely long periods without any notable difference being discernible between ancestor and descendant. Moreover, in some cases, varieties are found to revert to the character of the species from which they have proceeded. The conclusion has been drawn that the character of species is physiologically fixed; that is to say, that, however long the process of generation may be continued, the individuals either retain the identical morphological character of the oldest ancestor, or, if they vary, the varieties remain fertile with one another.

Assuming that species have the physiological character thus enumerated, certain conclusions respecting the "origin of species" are inevitable. It is clear that no existing species can have arisen by the intercrossing of preëxisting species, or by the variation of preëxisting species, but that every species must have existed from all eternity, or have come into existence suddenly in its present form, which is the objective fact denoted by what is termed creation.

At the dawn of modern biology, a century ago, no scientific evidence respecting the real history of life on the globe was extant, and, for any proof that existed to the contrary, species might have been of eternal duration. But philosophical speculation combined with theological dogma not only to favor the contrary opinion, but to lead the most philosophic naturalist of his day to embody the hypothesis of creation in a definition of species. "Totidem numeramus species quot in principio formæ sunt creatæ" (we reckon as many species as there were forms created in the beginning) is the well-known formula of Linnæus.

In practice Linnæus regarded species from a purely mythological point of view; in theory, he assumed the common ancestry and the limited variability of species, though he was disposed to allow more freedom in this direction than most of his successors. On the other hand, he seems to have attached comparatively little weight to the assumed sterility of hybrids, and to have held a sort of modified doctrine of evolution, supposing that existing species may have been produced by the interbreeding of comparatively few primordial forms.

It is mainly to the influence of Cuvier's authority that we owe the general acceptance of the views respecting the physiological character of species, which up till within the last few years have been almost universally prevalent.

In the introduction to the "Règne Animal" (1816), Cuvier writes:

> "There is no proof that all the differences which now distinguish organized beings are such as may have been produced by circumstances. All that has been advanced upon this subject is hypothetical; experience seems to show, on the contrary, that, in the actual state of things, varieties are confined within rather narrow limits, and, so far as we can retrace antiquity, we perceive that these limits were the same as at present.
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> "We are thus obliged to admit of certain forms, which since the origin of things have been perpetuated, without exceeding these limits; and all the beings appertaining to one of these forms constitutes what is termed a *species*. Varieties are accidental subdivisions of species.
>
> "Generation being the only means of ascertaining the limits to which varieties may extend, species should be defined, *the reunion of individuals descended from one another, or from common parents, or from such as resemble them as closely as they resemble each other;* but, although this definition is vigorous, it will be seen that its application to particular individuals may be very different when the necessary experiments have been made."

It need hardly be said, however, that in practice Cuvier founded his species upon purely and exclusively morphological characters, just as his predecessors and successors have done. The combination of Cuvier's views on the fixity of species with the discovery of the succession of life on the globe, which was so largely the result of his labors, led his successors into curious difficulties. Developing the fundamental idea of the "Discours sur les Révolutions de la Surface du Globe," naturalists were forced to conclude not only that existing species are the result of creation, but that the creative act by which they were brought into being was only the last repetition of a series of such acts by which the often depopulated world has been as frequently repeopled, and thus orthodox belief respecting the existing flora and fauna led to a terribly heterodox cosmogony.

The contemporary and countryman of Cuvier, Lamarck, must be regarded as the chief founder of the reaction against the doctrines which Cuvier advocated—a reaction which, overpowered and disregarded for many years, has acquired such force since and through the publication of the "Origin of Species," that it has almost swept opposition away. Lamarck's vast acquaintance with the details of invertebrate zoölogy rendered him familiar with the great variability of many species, and led him to see that variation is in some way related to change of conditions; the frequent occurrence of transitional forms between apparently distinct species, when large suites of specimens (especially when they are obtained from different parts of a wide geographical area) are examined, tended to bring into strong light the tenuity of the distinction between species and varieties. The fact of embryology, the occurrence of rudimentary organs, and the fundamental unity of structure which obtains in vast groups, such as the vertebrata and arthropoda, all tended to suggest the existence of a genetic connection between species, so that Lamarck was finally led to renounce the doctrine of the fixity of species, and to define a species as "a collection of individuals which resemble each other and produce their like by generation, so long as the surrounding conditions do not alter to such an extent as to cause their habits, characters, and forms, to vary."

According to this definition the distinction between species and variety once more becomes conventional. A variety is, in fact, a nascent species; and the notion of the creation of species vanishes, inasmuch as every species is the result of the modification of a predecessor. Lamarck's views of the nature of geological changes were in harmony with his biological speculations, and wholesale catastrophic revolutions were as completely excluded from the one as from the other.

It is impossible to read the "Discours sur les Révolutions" of Cuvier, and the "Principes" of Lamarck, without being struck with the superiority of the former in sobriety of thought, precision of statement, and coolness of judgment. And it is no less impossible to consider the present state of biological science without being impressed by the circumstance that it is the conception of Lamarck which has triumphed, and that of Cuvier which has been utterly vanquished.

Catastrophic geology has vanished out of sight, and is everywhere replaced by the conception of slow and gradual change. With it has disappeared the once prevalent notion that the whole living population of the earth has been swept away and replaced in successive epochs. On the contrary, it is now well established that the changes which have taken place in that population have been effected by the slow and gradual substitution of species for species.

Moreover, it is well established that in some cases the succession of forms in time is the same as that which should have occurred if the hypothesis of evolution is correct.

The rapid advance of comparative anatomy has diminished or removed the wide intervals which formerly appeared to separate the different divisions of the animal and vegetable kingdoms from one another. Even the hiatus between the vertebrata and the invertebrata is bridged over by recent discovery. The establishment of the cell-theory, however much the views originally propounded by Schwann have been modified, leaves no doubt that there is a fundamental similarity in minute structure, not only between all animals, but between them and plants, while the discoveries of embryologists have proved that even the most complex forms of living beings do, in the course of their development, run through a series of changes of the same order as those which are postulated by the evolution-theory for life in time.

Again, the facts of geographical distribution, as now known, are absolutely incompatible with the hypothesis that existing animals and plants have migrated from a common centre, whether Mount Ararat or any other; and, by demonstrating the similarity of the existing fauna and flora of any locality to that which inhabited the same area in the immediately precedent epoch, have furnished a strong argument in favor of the modifiability of species. Thus, it is not too much to say that the facts of biology known at the present day are all consistent with and in favor of the view of species entertained by Lamarck, while they are unfavorable to, if not incompatible with, those advocated by Cuvier; and that, even if no suggestion has been offered, or could be offered, as to the causes which have led to the gradual evolution of species, the hypothesis that they have arisen by such a process of evolution would be the only one which would have any scientific foundation.

The great service which has been rendered to science by Mr. Darwin, in the "Origin of Species" is that, in the first place, he has marshaled the ascertained facts of biology in such a manner as to render this conclusion irresistible; and, secondly, that he has proved the following proposition: Given, the existence of living matter endowed with variability, the interaction of variation with the conditions of existence must tend to give rise to a differentialism of the living matter into forms having the same morphological relations as are exhibited by the varieties and species which actually exist in Nature.

What is needed for the completion of the theory of the origin of species is, first, definite proof that selective breeding is competent to convert permanent races into physiologically distinct species; and, secondly, the elucidation of the nature of variability. It is conceivable that both the tendency to vary and the directions in which that tendency takes effect are determined by the molecular constitution of a living body, in which case the operation of the changes of external conditions will be indirect, and, so to speak, permissive. It is conceivable, on the other hand, that the tendency to vary is both originated and directed by the influence of external conditions, while it is also conceivable that both variation and the direction which variation takes are partly determined by intrinsic and partly by extrinsic conditions.—*The American Cyclopædia.*

# MALARIA.[1]

By CHARLES P. RUSSEL, M. D.

THE terms *malaria* and *miasm* in medical phraseology include the causes of a large class of affections—what are known more particularly as *zymotic* diseases, which depend upon a variety of specific organic poisons whose essential nature, composition, and form, are mostly inappreciable as yet by scientific research. The general understanding, however, of these terms, is more limited; and, in conformity with the popular idea, I shall in the present paper confine their application to the cause of those wide-spread disorders, *intermittent* and *remittent* fevers—the former of which is so well known as "chills and fever" or "fever and ague."

"Time out of mind," as Watson remarks, "it had been matter of common observation that the inhabitants of wet and marshy situations were especially subject to these definite and unequivocal forms of disease." The same natural agencies which are now at work elaborating, evolving, and disseminating malaria must have been equally in operation ever since the surface of the earth assumed its present condition. Vast and remote wildernesses that have never known human presence teem, as of yore, with deadly exhalations that almost preclude the bold attempts of enterprising man to lay bare their secrets. There are some parts of India, as Bishop Heber informs us, which even monkeys and other wild animals instinctively desert between April and October of each year. The tigers go up to the hills; the antelopes and wild-hogs make incursions into the cultivated plains; and those persons, such as *dâk-bearers* and military people, who are obliged to venture into the marshy jungles, agree that not so much as a bird can be heard or seen in the frightful solitude.

The celebrated Pontine Marshes may be regarded as the classic home of malaria. The older historical records describe this tract as occupied with numerous towns by the Volsci. It was evidently a fertile region; for we read in Livy that the early Romans sent thither during a season of scarcity for a supply of corn. Three hundred and twelve years B. C., the Censor Appius Claudius Cæcus constructed the Appian Way across the length of the Pontine region, the soil of which must then have been sufficiently compact to support the heavy causeway. At some period of the subsequent century and a half, the country seems to have undergone great deterioration either from natural or civil causes, and to have become partially inundated; for, about 170 B. C., we find the Consul Cornelius Cethegus applying himself to draining the marshes, and restoring the land to cultivation and salu-

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[1] A portion of a paper read before the New York Public Health Association, April 13, 1876.

brity. The result of his efforts was, that new and flourishing towns arose on the ruins of the ancient Volscian cities. The civil wars, however, and the devastation which accompanied them, again caused the hydraulic works of the Pontine Marshes to fall into neglect, until they were repaired by Augustus, who constructed several new canals, especially a navigable one skirted by the Appian Way. It was on this canal, at Forum Appii, that Horace embarked one evening, and at the same spot St. Paul first met his countrymen from Rome. Nerva and Trajan both contributed to the drainage of the Pontine Marshes, and left inscriptions, still extant, which testify to their great interest in the project. During the convulsions of the following centuries they were overflowed anew, until in the reign of Theodosius they were once more drained, with most beneficial effect, by a public-spirited individual named Cæcilius Decius. We have no subsequent account of the condition of this region until the end of the thirteenth century, when Pope Boniface VIII. constructed some works to drain it. Leo X. employed the engineer Giovanni Scotti to repair and enlarge the canal of Badino, the principal outlet of the marshes, and Sixtus V. built a large lateral canal. The most important improvements, however, were effected by Pius VI., and a system of effectual drainage was almost completed, when the low condition of the papal treasury and the confusion attendant upon the French Revolutionary invasion completely arrested the undertaking, which up to that time had involved an expense equal to $1,622,000. No new works have since been attempted, although the authorities endeavor to keep the canals clear and the dikes in repair. The greater part of the plain is covered with rich pastures; but, except the post-stations along the highway, and some scattered huts of herdsmen, it has and can have no permanent population.

Taking the United States census of 1870 as a guide for our own country, we find malarial fevers forming a very important feature of the mortality-tables. They are most fatal in Florida, Louisiana, and Texas. Next in order follow Arkansas, Mississippi, Alabama, Georgia, Missouri, Kansas, and Nevada. In another group distinguished by a somewhat less mortality we find New Mexico, the Carolinas, Virginia, Tennessee, Kentucky, Illinois, and Indiana. Those States marked by the lowest mortality are the New England and Middle States, Wisconsin, and Minnesota. In California there is a considerable ratio of mortality, diminishing easterly in Utah, and northerly in Oregon and Washington Territory, while it augments largely toward the south in New Mexico. Since the census was taken, however, that is, since about 1869, there has been noticed an evident extension of the subtile miasmatic agency over regions previously exempt from it, in the Middle and New England States. The increase of mortality by this cause in New York City has been notable, but can scarcely be attributed entirely to local influences. In 1868 there were registered in this city only 98 deaths from malarial fevers. In 1869 they rose to 128; in 1870, to 213; in 1871, to 291; and in 1872, to 348: an increase of 350 per cent. in four years. Since then some diminution in their fatality has occurred. They occasioned 282 deaths in 1873, 295 in 1874, and 275 in 1875.

Let us now consider under what circumstances malaria may be produced. Although it cannot be denied that there are peculiar localities where, with apparently every presumed condition existing for the development of malaria, that poison is entirely absent, yet the concurrence of malarial emanations with such conditions in innumerable places establishes beyond a question their direct relation. The *essential* element in the production of malaria would appear to be *vegetable decomposition;* and, in order that this process shall ensue, the simultaneous operation of *air*, *moisture*, and *a certain high range of temperature*, is absolutely required. Localities, therefore, where such combination occurs, are prolific of malaria. Of this character are swamps and morasses, alluvial deposits, loose, porous, sandy, and argillaceous soils, or deep, loamy, marly lands underlaid by impermeable strata affording capacity for the retention of moisture, regions exposed to periodical or occasional inundation, places left bare by the subsidence of lakes or drying up of streams, and particularly areas subject to the intermingling of salt and fresh water—as salt-marshes into which fresh streams discharge, or regions liable to tidal overflow and recession.

The exhalations from marshy tracts are recognized by their effects upon the human system throughout the world; and the fact that marshes bear a causative relation to malaria has been demonstrated in numerous instances by the disappearance of fever after thorough drainage and cultivation, and its reappearance upon their being allowed to relapse into neglect. The favorable effect of drainage and cultivation is owing both to the systematic removal of water near the surface, and most probably also to the absorption by the growing crops of the products of organic decomposition. On the same principle Prof. Maury succeeded in antagonizing the noxious emanations from a marsh surrounding the observatory at Washington by planting it thickly with sunflowers, which seem to possess an extraordinary absorbing power. Sebastian is inclined to believe that the *Calamus aromaticus* which grows in some swamps has a similar neutralizing quality. Swamps covered with water are not so dangerous as those partially dry, the layer of water serving as a protection against the access of air and heat to the vegetable matter underneath.

A certain continuous range of temperature seems essential to the development of malaria, which is almost unknown beyond 60° north and 57° south latitude, and during the cold season in the temperate zone. According to Hirsch, it prevails up to various degrees of latitude and average annual temperature. It is the average summer temperature, however, that is of account, and the northern limit of this lies between the isotherms of 59° and 59.8° Fahr., giving a prolonged temperature sufficiently high to insure vegetable decomposition.

The alluvial soil along the banks of rivers and at their deltas, as those of the Ganges, Nile, Orinoco, and Mississippi, gives rise to fevers of a very malignant type. Their banks are subject to overflow, and frequently have a clayey subsoil, presenting an obstacle to percolation —thus upon the river's receding into its ordinary channel its banks remain damp below the surface, and disease is generated by the sun's agency. A like process annually takes place in the extensive plains and table-lands formed of alluvium washed down from mountain-ranges during the lapse of centuries, and having few actual marshes. Profuse rains, succeeded by dry hot seasons, render such regions exceedingly insalubrious during certain periods of the year. Somewhat similar in character are the oases of the Desert of Sahara, which abound in malaria. Hirsch describes these spots as consisting of trough-like depressions in a rocky or highly-hygroscopic soil, the receptacle of subterranean waters, and covered with a layer of alluvium, the surface of the oasis. In this the fierce heat of the sun causes cracks and deep rifts in the earth, which give free vent to the miasm evolved from beneath.

Sandy plains, especially when at the foot of tropical hills and covered with vegetation, as the "Terai" at the base of the Himalayan range, are often infested with malaria. In other cases sandy plains at a distance from hills, apparently dry and not subject to variations in the ground-water, are equally sources of the poison. Such instances as the latter might seem to militate against the generally-accepted theory, but actually do not. Some sands which appear quite free from organic admixture are really the reverse. Faure has pointed out that the sandy soil of the Landes in Southwestern France contains a large amount of organic ingredient which is constantly decomposing and gives rise to periodic fevers. Under such sands, moreover, there is frequently a subsoil of clay. Here, then, assuming a continued high range of temperature, we find all the conditions necessary for the production of malaria.

Localities subject to the intermixture of salt and fresh water are particularly prone to malaria. The Maremmas of Italy afford examples of this on a large scale. The Maremma of Lucca consists of three basins formerly dotted over with ponds and pools. It had been for centuries frequently overflowed by the sea-tides which intermingled with its fresh ponds. Malarial fevers ravaged it and rendered it almost uninhabitable. To the wayfarer who was so imprudent as to spend a night of August or September within its desolate bounds, the penalty was almost certain death. A remedy for this deplorable condition of things was long sought. A proposition had been made in 1714 by the engineer Rondelli to attempt the exclusion of the sea.

Renewed in 1730 by Manfredi, and six years later by Zendrini, a mathematician of Bologna, the idea was finally carried into execution in 1740. The initial attempt was made upon the principal and most unhealthful basin. A sluice was constructed at the entrance of the canal of Burlamacca through which the waters of the sea penetrated into the basin to its central pond. The flood-gate was so arranged as to act like a valve, shutting by the pressure of the rising tide and opening when it fell. The success of this enterprise was so complete that in the following year the miasmatic diseases which had never failed to show themselves annually did not reappear, and the whole district was rendered salubrious. It was at this period that the village of Viarregio, previously abandoned and composed only of a few fishers' huts grouped at the foot of an old tower where galley-slaves were confined, became a place of fashionable resort during the summer for the aristocracy of Lucca. This fact of a region's being rendered healthy by the exclusion of sea-water is curious, but made more decisive still by its counter-proof. In 1768–'69 fevers suddenly sprang up again as bad as ever in the same territory. Upon the cause being investigated, it was found that the sluice had become deranged and the mixture of waters had been reëstablished. Upon the flood-gate being repaired, the malaria was again extinguished. The same occurrence happened in 1784–'85. The sluice having been neglected, there took place in 1784, out of a population of 1,900, the enormous number of 1,200 cases of malarial fever and 92 deaths. In the following year there occurred 103 deaths. The trouble was remedied in the same manner as before. The other portions of the Maremma were rendered healthy later, by sluices successively established at different points. Such a remarkable result necessarily attracted public attention. Leopold II., Grand-duke of Tuscany, was particularly impressed by it, and he conceived the great idea of improving the whole Tuscan Maremma in the same manner. It was an immense undertaking which he contemplated—an actual transformation of a large part of his dominions—and it redounds to his glory that he succeeded, in the face of almost insurmountable obstacles, by the means described, and a properly-directed system of canalization and field-culture, in regenerating a very considerable portion of his territory.

It is not difficult to account for the generation of malaria under such circumstances as those just mentioned. The minute forms of vegetable life with which both fresh and salt water teem require their own special element for continued existence. The intermixture of salt with fresh water introduces a new element with which the life maintained in each separately is incompatible. The surface of the soil consequently after every invasion and retirement of the tide exposes to the action of the heat a mass of defunct vegetable material spread out over an extensive area, and in most favorable condition for speedy decomposition.

Besides the localities enumerated, malaria is apt to be induced or intensified in a region wholly or comparatively exempt from it before, during the disturbance of large extents of soil, as in the construction of canals, roads, railways, fortifications, and dikes, rooting out of timber, preparation of virgin land for cultivation, etc. Vegetable organisms previously hidden and protected underground are thus brought to the surface and exposed to the agencies of putrefaction. Laborers engaged in such works and the neighboring inhabitants soon suffer. The "polders" of Holland, those parts reclaimed from the sea by the erection of dikes, are of this character, and the workmen engaged on them are attacked with malarial troubles of great severity. In this country such instances are common. We have an example at our very doors in the increase of malarial fevers which accompanied the opening of the new boulevards, and the engineering excavations of the Harlem Railroad. After such works have been completed, however, it is not unusual for the vicinity to be restored to healthfulness.

It must be acknowledged that occasionally miasmatic fevers appear and disappear without there having occurred any perceptible changes in the relations of the soil. Such circumstances were reported to the Pennsylvania State Medical Society as having been noticed in 1856 along the Juniata River. Reports to the Connecticut State Medical Society also mention the appearance of miasmatic disorders without any recognized cause in portions of the State previously exempt from them.

There would appear to be some connection between such phenomena and the fluctuating level of the subsoil-water as affected either by rainfalls or subterranean forces. According to Jilek's figures, in Pola, a noted malarious district of Istria, between 1863 and 1868 the number of persons attacked by fever varied from fourteen to fifty-one in every one hundred inhabitants, in exact proportion as the rainfall had varied from one to eighteen inches.

We know that the level of the ground-water is constantly changing. It rises and falls more or less rapidly, and at different rates in different places—in some only a few inches either way annually, but in many places several feet. In Munich, its limit was found by Pettenkofer to be about ten feet. In India, the changes are greater. At Saugor, in Central India, the extremes are between a few inches from the surface during the rains, to seventeen feet in May. At Jubbulpore it varies from two to fifteen feet from the surface. The causes of such changes are rainfalls, pressure of water from seas or rivers, and ob struction of outflow. The pressure of the Rhine has been observed to affect the water in a well 1,670 feet distant from the river. An impeded outflow which raises the level of the ground-water has been productive of an immense spread of paroxysmal fevers. Demster, Taylor, and Ferguson, have reported such to have been the case in portions of India. The severe and fatal fevers prevailing in Burdowan, Lower Bengal, during the last fifteen or twenty years, have been coincident with obstruction to the natural drainage from mills, and blockage of water-courses. The same cause has doubtless operated to a great extent in producing the fevers of Bloomingdale, Manhattanville, Yorkville, and Harlem. The establishment during the past five years of extensive subsoil drains in those portions of New York has had a visible tendency to diminish the area of malaria. A similar result on a large scale has been noticed in Lincolnshire and other parts of England, where many malarious tracts have been rendered quite healthy by similar measures, having for their object the lowering of the subsoil water-level by an increased outflow.

I have thus far confined my observations to endemic malaria. But, like other diseases dependent upon telluric or organic emanations, miasmatic fevers occasionally assume an epidemic character, and, breaking loose from their native haunts, overspread a wide extent of territory. Thus, as Hertz informs us, nearly the whole of Europe was invaded by such epidemics in 1558—in 1678–'79—from 1718 to 1722—from 1824 to 1827—and from 1845 to 1848. The cause of malaria being thus propagated is as mysterious as that of most epidemics. It is possible that such an epidemic malarial influence has been prevailing here; but we must not lose sight of the fact that sporadic cases of malarial fever appearing in non-malarial districts can frequently be traced to previous exposure in an infected locality.

Malaria, although having its ordinary habitat in low-lying regions, may under conditions favorable for its production exist at great elevations. On the Tuscan Apennines it is found at a height of 1,100 feet above the sea; on the Pyrenees and Mexican Cordilleras, 5,000 feet; on the Himalayas, 6,400 feet; on the island of Ceylon, 6,500 feet; and on the Andes, 11,000 feet. Sometimes, however, at considerable elevations it is unaccountably absent under circumstances apparently supplying every condition for its development. Thus, according to Jourdanet, close to the city of Mexico lies the lake of Tescudo, some twenty-five square miles in extent, composed partly of fresh and partly of brackish water, with a clayey bottom often laid bare over large areas as the result of evaporation under a temperature of 122° to 140° Fahr., notwithstanding which, malarial fevers seldom occur in its vicinity. At Puebla, Mexico, on the other hand, is a very malarious marsh 5,000 feet above the sea. Under ordinary circumstances, a certain altitude affords immunity from malaria, although low elevations of 200 or 300 feet above a miasmatic tract are often more dangerous than the flat lands—the poison seeming to float upward and become intensified. This was long noticeable on the heights of Bergen Hill, West Hoboken, and Weehawken, which overlook the Jersey flats. At present, the elevation of entire security is not positively determined, but it has been approximated as follows: in Italy, 400 to 500 feet; in California, 1,000 feet; along the Appalachian chain of the United States, 3,000 feet; in the West Indies, 1,400 to 1,800 feet; in India, 2,000 feet. In any of such regions, however, malaria may drift up ravines to an indefinite height. The agency of winds in transporting malaria for considerable distances cannot be questioned. Lancisi, author of the famous work "De Noxiis Paludum Effluviis," published in Rome in 1717, attributes to such influence the fact of the Roman Campagna having become unhealthy after the removal of the sacred groves exposed it to the currents of wind blowing from the Pontine Marshes. In later years, Barat accounts in the same manner for an epidemic of malarial disease which arose in 1869 on the island of Réunion, believing the poison to have been transported by the wind from Mauritius, where such affections were then alarmingly prevalent. In this instance none of the ordinary local causes could account for the outbreak. In four months, over 4,000 cases occurred in a population of 23,000. Salvagnoli and other observers affirm that malarial diseases increase in intensity, and penetrate farther inland on the island of Sicily and in South Italy during the sirocco laden with African miasm.

With regard to the question, "Can drinking-water act as a vehicle for the introduction of malaria into the animal system?" *a priori* it seems reasonable to suppose that such may be the case. If malaria, be it a gaseous substance or an accumulation of minute organisms, cannot pollute water, it differs essentially from other materials of similar form with which we are better acquainted. But, in fact, we have positive proof that malarial fevers may be due to drinking impure water. Mr. Bettington, of the Madras Civil Service, states that in that country it is notorious that the water may produce miasmatic fever and affections of the spleen. He mentions villages placed under similar conditions as to marsh-air, in some of which fevers are prevalent and in others not—the difference resulting from the former drinking marsh-water and the latter pure water. In one village there were two sources of supply—a tank fed by surface and marsh water, and a pure spring; only those who used the tank-water contracted fever. The celebrated instance related by Boudin is still more conclusive on this point. In 1834 there returned to Marseilles from Bona in the ship Argo 120 soldiers, of whom 103 were seized with various forms of malarial fever after drinking marsh-water taken on board at Bona. On the other hand, the sailors of the same vessel, who had pure water, and 780 men embarked on two other vessels, remained well. The few soldiers on the Argo not attacked had purchased their drinking-water from the sailors. Against such positive evidence as this the statement of Finke that in Hungary and Holland marsh-water is drunk without injury is of little value.

Now, a number of careful investigations have been made of the constituents of miasmatic marshes in various parts of the world, with the following results: They contain from thirty to thirty-five per cent. of vegetable organic matter. This consists of humic, ulmic, cremic, and apocremic acids, all substances requiring renewed chemical investigation. Various minute vegetable algoid forms are revealed by microscopic examination—bacteria, vibriones, and microzymes. But all these so-called impurities are found in nearly every running stream and in many harmless well-waters, and to condemn water on account of their presence would be really to reject all waters, even rain, in which minute algoid vesicles (protococci) are often found. Even distilled water may contain bacteria and vibriones. Although, therefore, admitting that water may be contaminated by the presence of malaria, it by no means follows that this poisonous ingredient has any relation to the organic impurities mentioned, or that the latter are in any way injurious, but we should none the less be cautious as to the source of our drinking-water.

The stratum of air overlying typical malarial marshes has also been examined with particular care. It has been found to contain an excess of carbonic acid—watery vapor in large quantity—often carburetted hydrogen, and occasionally free hydrogen, ammonia, and phosphuretted hydrogen. If the marsh contains sulphates, sulphuretted hydrogen. is present. Its organic matter blackens sulphuric acid—gives a reddish color to nitrate of silver—has a flocculent appearance, a peculiar odor, and affords evidence of ammonia. The amount in Becchi's analysis was .000118 grain in each cubic foot of air. Ozone had no effect upon it. Besides this organic material, various vegetable and animal matters are arrested when the marsh-air is drawn through water or sulphuric acid—*débris* of plants, infusoria, insects, and even small crustacea. Dr. Balestra has described spores and sporangia of a little algoid plant in the air of the Pontine Marshes. Lemaire and Gratiolet, in 1864, found in the air of one of the most unhealthy marshes of Sologne spherical, ovoid, and fusiform spores and a large number of pale cells, products, no doubt, of vegetable putrefaction. It has been supposed, by Schönbein and others, that ozone is deficient in marsh-air; that the quantity of ozone in the atmosphere and the prevalence of malarial diseases have an inverse proportion; and that ozone, by virtue of its supposed power of destroying organic matters in the air, is an antidote to miasm. There is, however, no evidence at all that ozone and malaria are antagonistic, or bear to each other any relation whatever. These various examinations, though interesting, bring us no nearer to a solution of the question, *What is the nature of malaria?* All of the many substances and forms thus far observed in malarial localities may be found equally in districts perfectly salubrious.

That it gains access to the system principally through the respiratory organs is quite certain. What we really do know of it has reference more particularly to its mode of action. It is most dangerous when the sun is down, and it seems almost inert during the day. It appears providential that the same agency which is so potent in its production should be the principal instrument of its destruction. It loves the ground, where in many regions it is so concentrated and deadly as to destroy the incautious sleeper on the earth almost as quickly as the most noxious gas. Hence it is generally regarded as having a specific gravity heavier than that of air, but this is by no means certain. It is doubtless rendered heavy by combining with night-fogs and dews, but upon their being dissipated by the sun it rises into the air and probably becomes innocuous by wide diffusion and dilution. It is intercepted by impediments, such as walls and groves of leafy trees, which obstruct the winds that bear it. Perhaps the latter also neutralize it by absorption. It is likewise neutralized and probably absorbed in passing over a considerable body of water—especially salt-water. The distance necessary to effect this result naturally varies with circumstances—force of winds, concentration, intensity, and abundance of the poison itself. According to Blane, in the channel between Beveland and Walcheren, 3,000 feet of water rendered it inert. In China, three-quarters of a mile, and in the West Indies, one mile, have been required to be effectual.

Recognizing the facts mentioned, the precautions to be observed against malaria are quite obvious. In built-up cities we are protected by pavements and sewers to a great extent, and probably also by the character of the atmosphere, which is artificially warmed by radiation at night, and impregnated with gases which, though injurious in other ways, are antagonistic to malarial emanations. But in malarial suburban and country districts it is otherwise. There certain precautions are necessary. If possible, elevation of a dwelling-place, at least 500 feet above the source of the miasm, is to be recommended in temperate climates, and from 1,500 to 2,000 feet in the tropics. If this be not practicable, thorough subsoil drainage, filling up of low and moist grounds, covering the earth with closely-cut herbage, belts of umbrageous trees interposed between the dwelling and the point of danger, but at a sufficient distance to permit free ventilation, and the access of sunlight; doors and windows opening principally away from the malarial quarter; the house, if possible, to be raised on pillars or arches a few feet above the ground, otherwise a sub-cellar thoroughly cemented—all these are measures of primary importance. The sleeping-apartments should not be below the second story, and should be provided with open fireplaces in which on damp or chilly nights a little fire may be kindled. Exposure to the open air after sunset, or until several hours after sunrise, should be avoided. As whatever tends to lower the vital powers predisposes the individual to malarial invasion, personal hygiene is indispensable. It should of course be dictated by common-sense, with the object of establishing and maintaining, in the words of the old maxim of the sanitarian, *mens sana in corpore sano.*

# ROCK-STRUCTURE.

By Rev. J. MAGENS MELLO, M. A., F. G. S.

THE study of rock-structure is one of great interest to the geologist, and not only does it teach him the various materials of which any particular rock is built up, but it will often lead him to the knowledge of wonderful facts relating to its origin and past history, and will enable him to trace some of the many changes to which it may have been subjected during the lapse of time.

I propose to illustrate this by taking some familiar specimen and showing the ways in which we may investigate its nature and history.

Suppose we take a piece of granite and see what we may learn about it. There are few persons but are acquainted with this rock in some one or more of the forms in which it is found. Our public buildings often present us with splendid illustrations of granite, sometimes roughly hewed, as it has come from the quarry; in other cases highly polished. We have seen the fine gray stones from Aberdeen, or the beautiful red ones from Peterhead and elsewhere. Now, when we begin to examine a piece of one of these granites, we see at once that it is not an homogeneous stone—such, for instance, as is a bit of flint—but that it is built up of various dissimilar-looking materials; and we may notice, moreover, that one or more of those materials is crystalline, that it is shaped in some regular geometrical form. We shall probably be struck with certain whitish or flesh-colored crystals, more conspicuously prominent than the other substances of which the specimen is composed. With some care we may be able to make out in part the form of these crystals, and perhaps to measure one or more of their angles; then, too, we shall notice that these crystals are apparently imbedded in a more glassy-looking substance of a clear and grayish color, and here and there we shall observe some bright spangles of a thin flaky mineral. We shall thus have seen the three principal minerals of which typical granite rock is composed; the larger opaque crystals, whether white or pink, are feldspar, the glassy mineral is quartz, and the little glittering spangles are mica. We may next proceed to a more detailed examination of each of these in turn. We will first ask the chemist what he can tell us of their composition. The chemist is not satisfied with merely knowing that a certain mineral occurring in certain definite crystalline or other forms is quartz, another feldspar, and so on; but he asks further: "What is this quartz? Is it a simple body, or is it, simple as it may appear to sight, a compound of two or more elements?" He takes various specimens of quartz, some perhaps from the granite, others from some other rocks, and subjects them to the analytical processes of the laboratory: the result is, that he finds all quartz, no matter what its color may be, whether white or pink or black, or pure and colorless as glass, to be a compound of the metalloid silicon and the gas oxygen; in other words, that it is an oxide of silicon, to which he assigns the name silica. By a series of analyses he is able to correlate the quartz of the granite with all other forms, and they are many in which this mineral occurs. The flint of the chalk, the white veins so often met with in the older slaty rocks, the agates picked up on the sea-shore and elsewhere, the beautiful crystals known as cairngorms, amethysts, and others, are all found to be but varying forms of the same substance, colored sometimes by adventitious matter, as iron, etc.; and he finds, too, that the exquisite skeletons of some of the sponges, the delicate valves of the *Diatomaceæ* and other minute specimens of organic life, consist of this very same silica, which is indeed one of the most important compounds entering into the structure of the earth's crust. Suppose the student next picks out one of the feldspar-crystals: this on analysis will be, as was the quartz, found to be also a combination; in it he will also find silica, but the silica in this instance is found to be combined with the metals aluminium and potassium—in fact, is a double silicate of alumina and potash. There are many varieties of feldspar: some of them differ from that most common in granite, which is called plagioclase, in containing lime or soda instead of potash; these are also distinguished from the orthoclastic series by their crystalline structure, which will afford, as we shall see, a ready method for their recognition, when they are

FIG. 1.—SECTION OF GRANITE FROM CORNWALL (POLARIZED), MAGNIFIED 26 DIAMETERS.

microscopically examined. When the granite rocks become decomposed, as they often do in Cornwall and elsewhere, through the wear and tear of the weather, we frequently find the disintegrated materials so separated that the silicate of alumina of the feldspar forms thick deposits of the beautiful white clay known as kaolin, and which is so valuable to the china-manufacturer.

The mica of granite is usually a variety called Muscovite, or potash mica; this again on chemical analysis is found to contain, as did the feldspar, silica, alumina, and potash, and also often some iron and manganese. There are several different sorts of mica, also, sometimes found in granite, especially Biotite, the composition of which varies from the above; but all the micas may be known by their being found in flattish crystals, which may be split up into an infinity of thin leaflets. Thus far our unaided eyesight and the help of the chemist have shown us what granite is made of; but we are now beginning to learn that, would we know something of the real history of a rock, a far minuter examination is needful, and geologists are rapidly learning that they must turn to the microscope if they would receive answers to many important questions, both as to the history and also as to the composition of rocks. A marvelous light has been shed during the past few years on rock-structure through this minute investigation, especially with the aid of polarized light. The intricacies of the closest-grained rocks have been disentangled, their component parts distinguished from each other, and the very order and history of their combination in the mass revealed. Now, when we examine our granite beneath the microscope, which can be done by having thin slices prepared, we shall learn something about it which we could hardly hope to have discovered without this aid. There has been much speculation as to the origin of granite, whether it is a plutonic—that is, an old volcanic rock—or whether it is only a deposit from water consolidated and altered during the lapse of long ages by heat and pressure: the microscope will help us to the truth. When magnified and examined with the polariscope, a thin section of granite is a very beautiful object, and its different constituent parts stand revealed with the greatest distinctness: we at once learn to see the crystals of

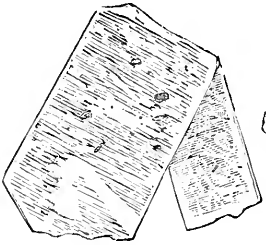

Fig. 2. Orthoclase Feldspar.

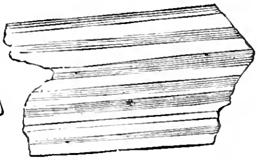

Fig. 3.—Plagioclase Feldspar.

feldspar, somewhat opaque and cloudy as they usually are in granite, but now and then clear and beautifully striped, and also the crystals of mica, imbedded in the clear quartz, which will be at once known by its bright clear colors and by the margin of rainbow-like tints which border its patches. Ordinary orthoclase feldspar is usually somewhat opaque and dirty-looking under the microscope, and by this it may be distinguished from the clear, glassy sanidine which is frequently found in igneous rocks, and presents under the microscope, when polarized, pure rich colors as well as sharply-defined crystals similar in form to those of the common orthoclase. The orthoclastic feldspars may be very readily distinguished from the plagioclastic by their structure, as revealed by the polariscope; the latter invariably are seen to be striped with variously-colored bands, showing what is called twin crystallization; and the orthoclase, though often forming twins on a larger scale, does not present the minutely-banded appearance of the plagioclastic feldspars. The mica in the granite section will not be difficult to recognize, especially if Biotite; often we shall observe it as forming fairly-shaped hexagonal crystals, and the polariscope will also help us to know it by its thinly-laminated structure, giving rise to fine parallel striæ on the surface of its crystals. Its colors, also, when polarized will be duller than those of the quartz, for which it might sometimes be mistaken at first sight, should it be a light-colored mica; and then, again, it will frequently be found that when the prisms of the polariscope are crossed the mica becomes perfectly opaque, its sections having been formed across the optical axis. But let us now look at the quartz. We shall observe that this quartz is generally not crystallized in definite forms, as are the feldspar and the mica; it appears as a matrix which has been at some time or other soft and so is penetrated by the other crystals, the interspaces of which it fills up: this shows us at once that it must have been solidified after them, and so was unable to assume its regular forms. This is a very remarkable fact, and helps us toward the secret of the formation of the granite. We know that quartz requires a higher temperature to melt it than does either the feldspar or the mica, and so, had the granite been formed as are regular volcanic rocks in the ordinary way of igneous fusion, we should certainly have found that the quartz would have crystallized before either the feldspar or the mica, and it

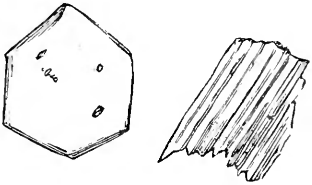

FIG. 4.—MICA (BIOTITE).

would have been seen in definite crystalline form, and its crystals would have interfered with and penetrated those of the other mineral constituents of the rock. Again, if we look carefully at the quartz with a moderately high power, we shall see in it certain small cavities, and some of these will be seen to contain a certain amount of liquid, and also an air-bubble, which will move as the specimen is moved. This liquid has been proved to be water, and from the fact of its not entirely filling the cavity we learn that a reduction of temperature has taken place since the water was first caught up by the quartz, causing the contents of the cavities to contract. Sometimes we shall find other cavities, which, instead of containing water, contain small crystals, or even air only. Now, from all these facts it appears tolerably certain that the granite was formed under peculiar circumstances; it has never been such a purely molten rock as is the lava of a volcano, which is poured out from its crater to the light of day. We gather that it was rather formed at great depths in the earth, where it may have been partially melted, partially subjected to the action both of water and of steam, charged with various mineral substances, and subjected to enormous pressure. What the original condition of granite was we cannot tell; some have gone so far as to think that it may have been that of a sedimentary rock, which has been metamorphosed by the forces just alluded to. But, whatever the primary state of granite may have been, its present condition shows it to belong undoubtedly to the igneous class of rocks, but to have been formed under conditions differing from those which have given rise to lavas reaching the surface. As far as can be gathered, the granite rocks, as such, have never seen the light of day until exposed by denudation, etc.; their origin was deep in the central portions of ancient volcanoes, where, by partial melting and slow cooling, under intense pressure, and in the presence of some water, the various minerals came together and crystallized into granite.—*Science-Gossip.*

# THE APOTHEOSIS OF STEAM.

By JOHN S. HITTELL.

IN a newspaper notice of a late book the critic complains that it is "an apotheosis of steam," an offense which he does not explain, but he conveys the inference that the book mentioned attributes to steam and to its age too much influence and importance in human life. He raises the question whether steam deserves apotheosis, and I answer affirmatively, undertaking to prove that, with its associate forces, it has conferred upon mankind benefits of vast, and, if considered absolutely, of unparalleled value; that the period since Watt's machine came into use deserves to rank as the leading era in history; and that it demands from us more study than either of the preceding ages of the press, iron, bronze, or stone, though they lasted much longer and have heretofore occupied much greater prominence in historical study.

Modern civilization belongs to the Euraryan—the Teutonic, Latin, Celtic, Slavonic and Greek—nationalities which migrated from Asia in the remote past to Europe, whence some of them passed over to other parts of the world, carrying their culture, their energy, and their high capacity for further progress, with them. The Asiatics, the Africans, and the aboriginal Americans and Polynesians, have for the last four centuries acted a part so subordinate in the great drama of human advancement, that they are like the shadows of a picture; they serve mainly as contrasts to bring out the brilliancy of the forms and colors in the light.

The age of steam—the period between 1770 and 1875—has trebled the Eurarÿans who have given us the enlightenment of the present, and are the hope of the future. Their number a hundred years ago was probably 120,000,000; though Gibbon, in the sixty-second note to the second chapter of his "Decline and Fall," following Voltaire, who was a respectable authority, said that Europe then had 107,000,000 inhabitants, including twenty-two in Germany, twenty in France, twelve in Russia, ten in Italy, eight in Spain and Portugal, eight in Great Britain and Ireland, seven in Scandinavia, as many more in Turkey, and four each in Hungary and the Netherlands. The facilities for getting information then were not so good as now, and, though Gibbon was very careful in his statements, yet he probably made a mistake in his figures. Kolb, in his "Hand-book of Comparative Statistics" (German, and not translated), tells us that France had 22,500,000 in 1770, Spain nine and one-third in 1768, Germany thirty in 1786, and Italy twenty in 1812; and Levi, in his "History of British Commerce," credits Great Britain and Ireland with ten in 1763. After excluding certain nationalities not of Aryan blood in Europe, and adding the British and Spanish colonists in America, we may estimate the total number of Euraryans in 1770 at 120,000,000. The present number is about 360,000,000, including three hundred in Europe, and forty-eight in North America. This great increase, far from being a necessary or natural result of the lapse of time, is entirely unexampled. The Roman Empire had about 120,000,000 inhabitants, and the same territory after a lapse of eighteen centuries had no more. Egypt 3,000 years ago, and Peru and Mexico before the Spanish conquest, had more inhabitants than now. As a general rule, population has been nearly stationary; century after century has passed, with little difference until we come within the magic influence of steam, and then suddenly the Euraryan race, acquiring the power to draw larger crops from the soil, to distribute them more evenly, thus preventing disease and famine, and to visit new and more profitable fields of industry, multiplies so as to keep pace with the increased supplies of food and with the demand for labor.

Education, like civilization, of which it is a large part, belongs mainly to the Euraryans. It is the misfortune of the Chinese and Japanese that more time is required to learn their hieroglyphical writing than to get a liberal education in a Teutonic or Latin tongue. The Arabs and Hindoos have alphabets, but they have no eminent schools, no rich literature, no great city in which their race has reached a leading place in culture. The possession of the alphabet, with the books, the schools, the wealth, and the centres of civilization, in the temperate zone, where man has the strongest stimulus and the most energy for the exercise of his physical and mental faculties, gives to Eurayans the mastery of the fortunes, and almost a monopoly of the interest of earth. Progress depends not so much on the number of those who come within its nominal domain, as of those who are under its full influence and appreciate its value; that is, the educated people. They have increased ninefold since 1770. In that year not one out of a hundred adults in Russia and Turkey, not ten in Catholic Europe, not thirty in Protestant Europe, could read. Now, about eighty-five out of a hundred in the Teutonic, and fifty in the Latin nations, can read, or nearly 200,000,000 in all. The gain in education is, however, much more than that indicated in the mere increase of those able to read. The quality of the learning has improved as much as its quantity. In the middle of the last century, there were few books worth reading in any modern language. A man was not accounted well educated unless he were familiar with Latin. So scanty were the literatures of French, English and German, that they were considered unworthy of the notice of scholars. The student had to read Greek and Latin to learn "the humanities." There was no science save dry astronomy and mathematics, little history, little philosophy, little poetry. The chemistry, geology, and physiology, which form the bulk of our positive knowledge, are products of the steam age; and, instead of being dry and remote from the business and associations of practical life, they come home to us every day, guarding our health, assisting our industry, and influencing our opinions. Ancient Egypt, Assyria, and Hindostan, and the prehistoric man in Europe, have been made known to us by late research, and even our histories of Greece and Rome have required rewriting, to adapt them to the advance of our knowledge and philosophy.

A large majority of our most instructive books are the product of the last hundred years. Of the works sold in the book-stores or loaned by the public libraries, at least ninety-five per cent. are new. Nearly all our prose romance, and most of our poetry, history, and miscellaneous literature, belong to the steam age in origin and spirit. We now write ten times as many books, and publish fifty times as many volumes annually, as they did in the last century. The United States turns out 2,000 and Great Britain 4,000 new books every year, and the other Euraryan nations probably bring the total figure up to 15,000; whereas, before the middle of the last century, the number was probably not more than 1,500. Besides the books, we have now 7,000 newspapers which are new, and in the aggregate furnish as much material for reading, and contribute nearly as much to education, as the books.

The commerce of the world has been revolutionized in the age of steam. Many obstacles which stood in the way of its development in 1770 have now been removed. National animosities, sectarian passions, popular ignorance, despotic governments, the division of one nationality into numerous independent states, and the established policies of conquest, balance of power, sectarian intolerance, and trade-restriction bred frequent wars, and destroyed confidence in the duration of any peace. Hostilities were waged with little regard for the property or persons of non-combatants; and plunder and devastation were among the common accompaniments of invasion, and were recognized as customary rights of the invaders. The uncertainty of enjoying accumulated wealth deprived the people of zeal for labor or economy. But now there has been a vast change for the better, and commerce and finance have made wonderful advances. International and national traffic have risen to proportions which far surpass the wildest visions of past ages.

In the middle of the last century a turnpike, covered with gravel or broken stone, was a rarity even in the neighborhood of the great capitals; and for every mile of such road, and for every stage running regularly to carry passengers then, there are now a thousand. Travelers were few, and usually went on horseback. Not a hundred years have elapsed since the owners of riding-horses petitioned the English Parliament to forbid the establishment of a stage-line which had lately been started, and was ruining their business. In 1763 one stage left London for Edinburgh each month, taking nearly two weeks to make the trip each way; and in 1810 only two hundred and twenty travelers entered Paris by stage in an average day. The increase has exceeded a thousand-fold. England did not commence building canals till 1760, and in the mean time not less than 6,000 miles have been built by the Eurarvans, at a cost of not less than $500,000,000. The shipping of Christendom has risen from 1,500,000 to 15,000,000 tons, and a third of the increase is in steamers, which make three trips for one by a sailing-vessel. They not only carry three times as much freight per ton as the sailers, but they take many perishable articles which could not go by the slower navigation, and were therefore not produced, or were wasted. There has been a vast increase in the construction and in the number of freight-wagons for common roads; and the railroads, with an aggregate length of 140,000 miles, and a cost of $2,000,000,000, are new. The freight which cost thirty cents a ton from London to Manchester in 1825 now costs one cent. Counting the macadamized roads, the new and improved wagons, the canals, the river and ocean steamboats, the increase in the number, and the improvements in the size, pattern, rigging, and speed of sailing-vessels, and the railroads, there is no exaggeration in saying that the facilities for domestic and foreign commerce have increased one hundred-fold.

And then the gain in the materials for commerce has been immense. Steam-engines furnish a power estimated to be equal to that of 300,000,000 working-men, and the saving of labor by other machines is probably not less. The production of cloth and the manufacture of iron have been revolutionized, and the annual consumption of the most useful of metals has increased from 200,000 to 12,000,000 tons. The industrial arts generally have made so much progress, that no extensive branch of business is now conducted as it was in the middle of the last century. Our houses, our tools, our clothing, our food, our trades, and our professions, are different in many important points. The farmers have thrown aside the wooden plough, the sickle, and the flail, which were their chief implements in 1750. The wooden mould-board was excellent as compared with the barbaric plough which had no mould-board, and did not throw a furrow to one side, but merely scratched the ground, making a ridge on each side of the plough-point. While oak was the material, the farmer usually hewed or chopped out his own board, and fastened it on his plough; but both the shape and the adjustment were bad, and the surface, from the nature of the material, would never "scour" well in the moist earth. I accord to Scotland, on what appears to be a preponderance of evidence, the credit of producing the first iron mould-board, though the claim is contested by the United States, where the invention was first generally appreciated, and perfected by various small improvements. The superiority of the iron plough in form, adjustment, and surface, made a vast saving in friction; the furrow was turned over more regularly; the weeds were killed more thoroughly; the pulverization was better; and the working capacity of the ploughman and the productive capacity of the soil were each nearly if not quite doubled; so that now, France, with a smaller number of men engaged in the business, yields three times as much wheat at an average harvest as it did about 1770. Since the farmers are the largest class of producers, and the basis of national prosperity, and since ploughing is the most important part of their labor, the invention of the iron mould-board deserves to be considered one of the greatest contributions to modern civilization, ranking next to the steam-engine and to movable type, in its influence on the general condition of mankind.

The sickle was superseded by the cradle, with which the farmer could cut four times as much, and that by the reaping-machine, with which a man can cut five times as much, as with the cradle. The scythe gave way to the mowing-machine, and the flail to the thrashing-machine. The steam-plough has not yet been introduced extensively, but it will doubtless make another revolution. The progress made in the drainage of land by pipes, in the drying of fruits and vegetables by hot air, and the canning of fruits and meats, all are important aids to agricultural industry. The breeds of farm-animals have been greatly improved. The Ayrshire, the Durham, the Jersey, and the Devon, the Cotswold, the Southdown and the Cheviot, the Chester and the Berkshire, the Clydesdale and the American trotter, have been either started, or for the first time introduced into extensive use, in the steam age.

The miner has adopted dynamite and other explosives stronger and safer to handle than the charcoal-powder, and can, at the same time, hold and strike the small drill, whereas the large drill needed for the weaker powder required one man to hold the drill while another was striking. Steam not only hoists the ore and pumps the water, but sometimes drills the rock. The method of stoping toward the shaft has been introduced. More important still is the general education of the superintendents in engineering and chemistry. The processes of separating gold and silver from the earthy and rocky matter which hold them in a state of nature are new in their principal features.

All the prominent mechanical occupations have felt the influences of our progressive time, and many have been added to the list. Nearly every labor-saving machine has called a new trade into existence. The builders of stationary engines, of locomotives and of railway-cars, the boiler-maker, the steam, the railway, and the gas engineers, the gas-fitter, and the manufacturer of chemicals, are a few out of many. Planing and moulding machines, and circular and band saws, wire ropes and iron bridges, "balloon" house-frames, fastened together with nails, and without the old style of mortices and tenons, and machines to make cut-nails and wood screws, have had much influence in mechanical business. If steel pens had not come into use as a substitute for quills, the supply of which would have been entirely inadequate to the scribbling demands of the present day, education might have felt a check. The steam-press, the turbine-wheel, the type-casting machine, lamp-chimneys which secure better light with less smoke, kerosene-lamps, cleanly stearine-candles instead of the dirty tallow, are all to be credited to the steam age.

The railroads and the steamboats have covered the land, the rivers, and the lakes of Europe and North America with the beneficent network of their routes, and have given a new life to commerce. The exports of Great Britain in 1770 amounted to $65,000,000, and in 1870 to $1,220,000,000. In the same period the measurement of the shipping owned in that country increased from 550,000 to 7,100,000 tons, and that of the shipping entered in a year from 890,000 to 18,000,000 tons. The amount insured rose from $850,000,000 to $6,800,000,000.

The greater part of the increase in commerce since 1770 has occurred within the last fifteen years, and the annual gain now is greater than the total traffic in the middle of the last century, and tenfold greater than the traffic at any time before the discovery of America.

The advance in the other nations of Europe generally has not been so rapid as in England, yet it is remarkable. The exports of France rose from $400,000,000 in 1840, to $700,000,000 in 1869; those of Austria from $40,000,000 in 1842, to $160,000,000 in 1869; and those of Russia from $50,000,000 in 1851, to $125,000,000 in 1869. In the United States the progress has been more rapid than in England. The total aggregate value of the exports and imports (excluding the precious metals) of the fifteen leading commercial nations was $6,000,000,000 in 1860, and $9,500,000,000 in 1870. These figures are astounding, and nothing but figures can give us a correct idea of the overwhelming magnitude of the present, and the relative insignificance of the past. And if now commerce gains nine per cent. annually, whereas before the steam age it did not increase one per cent., shall we not exalt the age of steam, which has brought the improvement? It is to be observed that the forces which have caused the wondrous development, instead of having reached the culmination of their influence, are only beginning to get full swing, and that the new commerce has not yet had time to exert its power. Statesmen and people do not yet comprehend the vastness of the commercial interests, nor have the merchants and capitalists yet learned how to combine to prevent the legislative follies of past ages. Commerce is destined to be the great bond of peace between nations, and they will be compelled soon to organize a league to administer international justice, and to protect the vast interests involved in their trade. They must adopt new rules for their new circumstances. The policy which might have been beneficial in a national point of view in 1700 would be foolish now. "Commerce," as John Stuart Mill said, "first taught nations to see with good-will the wealth and prosperity of one another. Before, the patriot, unless sufficiently advanced in culture to feel the world his country, wished all countries weak and poor and ill-governed, but his own." Now, he understands that the greater their wealth and prosperity, the greater also will be that of his nation; in the same manner as the individual merchant or mechanic thrives better with rich than with poor neighbors and customers. But we are told that the spirit of our age is bad; it is too materialistic; it is hostile to æsthetical and spiritual influences; it exalts money and machinery. The meaning of this complaint is that its authors have not been properly educated, and they find that the world is not in sympathy with them. They measure it by their ignorance and prejudice, and conclude that it is wrong. In all ages such lamentations have been heard about the progress of the most beneficent changes. The discredit into which many of the old metaphysicians have fallen is chargeable in a great degree to our superior knowledge. We have discovered that their premises were false, and of course we care nothing for their conclusions. I assert that poetry, painting, sculpture, and architecture, never within an equal period produced so many great works as since 1770, but I have not here the space to argue that point.

I think the proof is sufficient that there has been an immense change in human life for the better since the middle of the last century—a change great enough to require the recognition of a new era in culture. The preponderant influence and characteristic of our time suggest that it should be called "The Age of Steam;" and this, like the universally-accepted stone, bronze, and iron ages, suggests that industry is the most important feature of culture. No other name has been offered, no other force can compete with it. The improvements in printing and in the manufacture of iron and cloth, great as they are, are yet dependent for much of their value on the steam which drives the press, the rolling-mill, and the loom, and transports their products to market. The electric telegraph is inferior to either of these three: Watt's invention remains master of the field. It has made a new era, which ranks with that of bronze, and the two surpass in importance all the others.

When savages learned to make bronze, their former weapons and tools of stone and bone were thrown away. The flint knife, which lost its brittle edge at the first cut into wood, was replaced by tough metal which could be sharpened anew every day, and would last for years. The clumsy obsidian spear-head, that flew to pieces at the first throw, was superseded by another of better shape and more durable material, fitted for the wear of centuries. The savage armed with flint weapons was no match for the man of bronze, and thus the latter could take the most fertile valleys and reduce the former to slavery. The possession of metallic hoes, spades, and sickles, was the beginning of systematic agriculture. The soil began to produce abundantly; the supply of food was larger and more constant; population became dense; buildings of cut stone were erected for temples, fortifications, and granaries; the accumulation of property became possible and reputable; nations were organized and armies drilled. All these changes were the necessary results of the discovery of the art of making bronze. Previously men were in the stone age, without durable houses, without national government, without cities, without any accumulation of property, division of labor, literature, or prospect of progress.

The iron and printing ages made revolutions in society, but they were far less important than those of bronze and steam. The bronze revolution was the greater, looked at from a relative standpoint, but, considered absolutely, it was small in comparison, and very slow in progress, with the influence of steam. The ancient Egyptians asserted that their monarchy had stood without material change for 10,000 years. There is much reason for believing that their religion and polity were about the same for at least 3,000 years, and for presuming that they must have been very slow in reaching that condition. The farther we look back into history, the longer we find the intervals between the permanent improvements of culture. The present age is resplendent not less for the magnitude of its inventions and discoveries than for the speed with which they have crowded upon one another's heels, and have been carried round the world. No previous time has approached ours in its achievements, and, if ever any force of culture deserved apotheosis, it is steam.

# ON THE BACKWARDNESS OF THE ANCIENTS IN NATURAL SCIENCE.

By CARL VON LITTROW.[1]

I CAN hardly be mistaken in holding that the ceremonies attending the installation of a rector of our university chiefly concern the students. Thus only can I account for the fact that on the one hand the newly-installed officer is burdened with the unpleasant duty of listening to a history of his own life, and, on the other, that he is required to deliver an address whose sole purpose is to make known the ground he occupies in science and in his teaching. His colleagues, to whom he is indebted for his election, of course have no need to be informed where he stands, while the students oftentimes have but scant opportunity of knowing what manner of opinions are held by him. Hence it is that my words are addressed first of all to you, my young friends.

Those nations of antiquity which so long freely and unchallenged have borne the title of "classical," owe to their mastery of form whatever right they have to that honorable epithet. While we must regard our predecessors in culture as being the best patterns in all that regards form, we may nevertheless of ourselves assert that in the investigation of matter, and in the arts of making it subservient to man, we in turn equally or even to a greater degree surpass the ancients. This condition of things is indeed nothing but one phase of the strife between the real and the ideal—a strife which, fortunately for mankind, is never altogether allayed. That in nearly every department of art—taking this term in its widest sense—we are on the whole the miserable Epigoni of the ancients, is universally admitted,

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[1] Inaugural Address on his installation as Rector of the University of Vienna. Translated by J. Fitzgerald, A. M.

and the causes of our inferiority are well enough understood. On the contrary, the reasons of our own preëminence in the exact sciences are by no means so generally known. Schiller, who, had he not been a profound philosopher, would never have been the prince of poets that he was, describes the realist as being characterized by a spirit of "sober observation," and the idealist by a spirit of "restless speculation." "When we presume," says he, "by the mere force of reason to determine anything about the outer world, we do but trifle." However obvious the meaning of this remark may at first appear, we shall find, on closer consideration, that in fact the author not only ascribes to the idealistic mind of antiquity an undue bent toward speculation, but that furthermore he plainly denies to it the faculty of correct observation. The entire justice of Schiller's remark, whether as taken in its literal or in its implicative sense, is perhaps nowhere so patent as in the province of astronomy.

Every one knows of the clear skies which canopy the homes of the early civilizations—Italy, Greece, Spain, Egypt, Arabia. The purity of the atmosphere enjoyed by these regions is shown by the importance attached by the ancients to the knowledge of the rising and setting of certain stars. In our countries astronomy must have been precluded from taking the same direction by the fact that but rarely do we see the stars near the horizon, to say nothing of seeing them on the horizon, owing to the presence of haze, which in these regions nearly always narrows the field of view. For this reason, had we not the telescope, we should have been unable to attain to the comparatively accurate knowledge possessed by the ancients with regard to the movements of Mercury, a planet which is hardly visible from our latitudes We inhabitants of Central Europe might easily, in point of cloudy skies, be the rivals of the dwellers on the shores of the Sea of Azof—the Cimmerians of the ancients. It might therefore be supposed that the starry heavens, as these ancestors would describe them to us, must be in great part invisible to us, and far richer than we have been able to see them in later times. We must the more expect them to describe things hardly visible to us as our present division of the northern heavens into constellations dates, as far as its main features are concerned, from at least 2,000 years ago, and the firmament formed an object of studious contemplation even then. Add to this the fact that, as early as the year 130 B. C., Hipparchus began to draw up a complete catalogue of all the fixed stars; and Claudius Ptolemæus, 150 years later, took up this task anew. Now the "Almagest," as Ptolemy's work is called by the Arabs, who handed it down to us, includes 1,028 stars; and even if, on the strength of a remark made by the elder Pliny, who speaks of 1,600 observed stars, we with faint probability grant that the "Almagest" does not represent the complete labors of Hipparchus and Ptolemy, still even the second figure is far less than we should have expected. Argelander, at Bonn, sets down in his charts no less than 3,256 stars visible to the naked eye; and Heis, whose eye indeed was possessed of an abnormal power, seeing stars as points without rays, increased Argelander's list by 2,000 stars visible at Münster. Thus, not taking into the account the no less than twenty more degrees of the heavens visible from Alexandria than from Germany, the ancients noted hardly one-half of the stars which were visible to them! The defectiveness of their observations can be more easily understood from the fact that for instance they reckoned 474 stars of the fourth magnitude, only 271 of the fifth, and finally only 49 of the sixth magnitude; whereas the fact is, that the number of stars increases so rapidly in the order of magnitudes that each succeeding class embraces a much larger number than all the classes that precede it. In our latitudes Argelander makes out with the naked eye nineteen nebulæ and star-clusters, while Hipparchus mentions only two, and Ptolemy five, neither of them noting such prominent objects as the nebula in Orion and that in Andromeda. And such defective knowledge as this of the open-lying heavens persisted long after the invention of the telescope—for full 1,500 years. Among the old astronomers the Persian, Abdalrahman-Al-Sûfi, who lived in the tenth century, forms a notable exception; but he did not inspire his contemporaries or his successors with his own ardor, or prompt them to add to his labors.

The same is to be said of the southern heavens. The Arabians, surely, did not lack opportunity for acquiring a knowledge of many of its constellations. Ever since the days of Bartolomeo Diaz, it was a necessity for Europeans, on sea-voyages, to determine places by southern constellations. Ptolemy was acquainted with only a few of the principal stars of the antarctic hemisphere, and it was not till the beginning of the seventeenth century that Theodor von Emden regularly divided these regions of the heavens into constellations. It remained for Herschel, in recent times, to determine a number of open questions with regard to these southern constellations.

To account for this backwardness in the investigation of a subject which certainly possessed at least as much interest for the ancients as for ourselves, by declaring it to be the result of their superficiality, were an injustice to the olden time, seeing that in other respects it commands our unconditional admiration for its arduous achievements. That what they needed was to have their senses trained to this kind of work, and that, although they had keen appreciation of art, they never learned to look at things with the eye of the investigator of Nature, will be better understood from a statement of what they knew about individual celestial objects than of what they knew about the entire firmament.

That well-known group of stars, the Pleiades, which in the Fall adorns our eastern sky by night, serves well to show that in observing the stars something else is required besides a clear atmosphere and good eyesight. In a didactic poem by Aratus, written 270 years B. C., we have our earliest trustworthy account of Grecian astronomy. There the Pleiades are called "*ἑπταπόροι*"—*stars traveling in seven paths*—though according to Aratus only six stars were visible. Some 300 years later Ovid writes—

> "Quæ septem dici, sex tamen esse solent;"[1]

while Hipparchus, in his critique of Aratus, about 150 years before Ovid, expressly says that in clear, moonless nights seven stars can be actually made out. Now, Aratus lived in Macedonia, and Ovid apparently wrote his "Fasti" at Rome, giving the finishing touches to the work on the southern shore of the Black Sea: thus both writers lived beneath a very clear sky. The fact that Hipparchus labored at Rhodes, a few degrees farther south, must not be supposed to account for his having seen one more star than the others, though the discrepancy between the observers is all the more surprising as the group about which they differed was of great importance for navigators in the then state of nautical science, and was constantly under observation. This circumstance, in fact, attracted the attention of the astronomers of the time, but for centuries they sought in vain for the seventh star, and offered all manner of curious explanations for its supposed disappearance, one of which is worthy of special mention, viz.: that this seventh star had moved over to the position of the middle star in the tail of Ursa Major, called by the Arabians Mizar, and that it was the little star now commonly known as the Postilion and which stands close to Mizar. The scholia to Homer cling to this idea of the disappearance of the seventh star. Not until the thirteenth century do we find a correct description of the Pleiades, in a work by the Persian astronomer Kazvini, who apparently borrowed it from Sûfi. "There are," says Kazvini, "six stars (in the Pleiades) and in the midst of them a number of dark (i. e., faint) stars;" but his observations received no attention from subsequent astronomers. In vain, too, was the observation even of such a man as Maestlin, Kepler's preceptor, who distinguished no less than fourteen stars in the Pleiades group. Not till after the invention of the telescope could Sir Christopher Heyden, in 1610, write as follows, showing the power of the new instrument: "I see with my telescope eleven stars in the Pleiades, though never before were more than seven distinguished." But how stands the case to-day? At present they who discern these eleven stars with the naked eye are considered anything but prodigies; indeed, I am acquainted with persons—not professional astronomers, but laymen—who can make out from fourteen to sixteen stars in this group. But then we are the descendants of generations of men who from infancy were taught to put their organs of sense to the sternest test, and to take note even of the faintest sense-impressions; our eyes have been schooled, and

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[1] Said to be seven, though they number only six.

in this special instance of the Pleiades they are not so much dazzled by the brighter stars as guided by them to the stars in their neighborhood, for, in fact, more than one half of the fourteen stars are of a magnitude far below the commonly-accepted limit of vision for the naked eye. We have learned to observe, to choose favorable conditions, to know what is a really clear atmosphere; we know that small stars in the vicinity of bright ones are far more readily descried in twilight than in the depth of night, the brightness of the larger stars in the latter case obscuring the smaller. Hipparchus errs in saying that moonlight is a hinderance to such observation: keen eyes may, with a bright full moon shining, count as many as fifteen stars in the Pleiades.

Another point of considerable interest we note in this instructive example. The fact that the Postilion, the Alcor of the Arabians, was taken to be the lost seventh star of the Pleiades, further shows that Alcor, though a star of the fifth magnitude, and easily discernible, had not been noted by previous astronomers, else it could never have passed, at the beginning of our era, as a new star, then first registered. And indeed the Arabian astronomers, one thousand years later, call this star "The Forgotten," plainly because it had not been noticed previously.

We have a like instance in the star Alpha in Capricorn. Mankind had to observe this star for thousands of years before they saw, what any child may see when its attention is directed to the object, that here are two stars (one of the third and one of the fourth magnitude) so close together as to coalesce into one when hastily viewed. Again, it was the Arabians who noted this circumstance. Still, this did not avail to establish the true nature of *a* Capricorni. Ulugh Beigh, in the fifteenth century, and Tycho Brahe, in the beginning of the seventeenth, in their famous "Catalogues of the Stars," take no notice of it, and it was not till one hundred years later that Hevelius formally entered the companion-star in his list. We cite two or three further instances to show how the idealistic bias of the ancients, which culminated in Aristotelism, has almost down to our own times diverted men from simple but correct views of the world of sense.

The amazing progress of observational astronomy during the last two centuries is in great measure due to the happy accident of our hemisphere containing a bright polar star. Sundry investigations can be made only with regard to stars near the pole, and all the more easily, of course, and with smaller instruments, the larger the star happens to be. The importance of this star impressed itself upon men in former times, it being employed for correcting the compass. And yet even Columbus was not clear whether Polaris is situated at the north-pole, or only near to it, though it must be observed that in his day its distance from the pole amouted to more than three degrees, i. e., about six diameters of the full moon, and that hence it could not altogether escape his means of observation. "It appears," he cautiously observes, "as if the pole-star had a motion [round the pole] like the rest of the stars."

Again, is it not amazing that for thousands of years mankind should have been in presence of so frequent a phenomenon as the zodiacal light—a phenomenon which in southern latitudes is specially impressive—without considering it to be worthy of mention, or rather, let us say, without *seeing* it, until Childrey, in the middle of the seventeenth century, *discovered* it, if we may so speak? So, too, may it excite our wonder, to think that the earliest definite mention of the noteworthy phenomena (easily visible with the naked eye) attending a total eclipse of the sun dates only from the year 1706, that is to say, a period of time full one hundred years subsequent to the invention of the telescope.

Thus the ancients were deficient in even the most elementary powers of observation. The simple but truthful noting of what is perceived by the senses is the prerogative of our time. But what of the restless spirit of speculation with which Schiller taxes the ancients?

Here permit me to recall anew to your memories, by an instance taken from the history of astronomy, thoughts which oftentimes, perhaps, have occurred to us all. Plutarch's dialogue on "The Visage that is seen in the Moon's Disk" has ever been regarded as containing the sum and substance of all man's notions and knowledge of our satellite down to the period when it was written. The very title is provocative of mirth to us, the children of the modern time. The Visage in the Moon! Nowadays it only suggests to the poet and the artist satirical ideas: in olden times it was the starting-point of profound meditations, which were held not to be unworthy of being attributed to the most famous philosophers and mathematicians of the day. The author first in all earnestness demonstrates the absurdity of the opinion which asserts the figure appearing in the moon to be nothing else but an optical illusion arising from the visual sense being dazzled by the brightness of the moon's disk. Next we have a lengthy refutation of another opinion, which says that the visage in the moon is the reflection of our ocean. Among other reasons given to show the erroneousness of this opinion is this, that there is only one ocean, and that, if the visage in the moon were a reflection of it, then the ocean must be made up of parts separated from one another by isthmuses and continents! The third opinion combated by Plutarch is to the effect that the moon is a mixture of air and of a mild kind of fire; as sometimes during a perfect calm the surface of a body of water becomes ruffled—a thing itself to be demonstrated—so too does the air assume a blackish color: thus is explained the appearance as of a human face in the moon. The hypothesis of the Stoics, who affirmed the moon to be a globe of fire, on the surface of which rests the atmosphere, is rejected on the ground that in that case the moon would need some matter whereon to rest, and from which it might derive fuel for its fire. We are informed that, according to Pindar, the earth is propped up all round by pillars with bases of adamant, whereas, according to the Stoics, she has no need of supports, being situate in the centre of the universe toward which all things tend. This last opinion is declared to be untenable, because the earth, whose surface is so broken with elevations and depressions, must then be considered as spherical, and that would imply the existence of antipodes clambering up and down the earth's sides like lizards. Coming back to the principal question under discussion, the solitary interlocutor in this dialogue maintains that, even granting the impossibility of ponderous, earth-like bodies moving in the heavens, it does not follow thence that the moon is not another earth, but only that it happens to be in a region to which it does not by its nature belong. Man, for example, in like manner has his ponderous, earth-like parts in the upper region of his body, in the head, and the warm, fire-like parts in the lower; of his teeth some are directed downward, others upward, but in neither is there anything contrary to Nature. The moon, situate between the sun and the earth, as the liver or other soft viscus lies between the heart and the stomach, transmits heat from the upper regions to us, at the same time dissipating the mists which rise from the earth, purifying and attenuating them by the action of her own heat. Considered as an earth, the moon is a splendid body; as a star it would be a shame to its class; for of all the innumerable heavenly bodies—to quote the author literally—she is the only one that needs another's light! When the sun goes down he is hidden from us by the earth; in an eclipse, on the coutrary, by the moon. Hence the earth, owing to its great size, covers the sun entirely, as long as the night endures, while the moon sometimes conceals him totally, but only for a short time. The moon, therefore, is a body like our earth; and inasmuch as it contains nothing that is foul, and enjoys the purest light of heaven, and is filled with genial fires which do not consume like the fires of earth, the moon must contain the most delightful savannas, flames like mountains of light, empurpled zones, and abundance of gold and silver; all this—accounts for the visage in the moon's disk! The objection that the spots on the moon are too large to be thus accounted for is met with the noteworthy proposition that it is the remoteness of the light from the body casting the shadow, and not the size of the body, that makes a shadow large; and if Mount Athos casts a shadow 700 stadia in length, that is a consequence not of its height, but of the sun's great distance. The discussion here is diverted to the question of the habitability of the moon and the fate of our souls after death; of this argument I need only quote the comforting assurance that the devout and the virtuous migrate to the moon, and that from the ether in which they float they acquire an elasticity and a strength, for the maintenance of which the most attenuated vapor affords sufficient nourishment.

However incomplete this summary of Plutarch's voluminous tractate, it will serve to convey some idea of the state of astronomy and physics among the Greeks. In it we look in vain for simple recognition of the facts, or for any just apprehension even of the most elementary principles. Approaching their inquiries with foregone conclusions, they had decided the causes of phenomena long before they came fairly within range of them.

The point therefore is, not merely *what* we see, but also *how* we see; we must be able to critically examine what we have seen, and, above all, we must be able to recognize those features of the object which are of importance. And, as in the foregoing examples we have shown that in the domain of science *mere seeing* was not the strong point of the ancients, so it can be proved that they were even less distinguished for *reflex seeing.* By way of antithesis to a generally-received proverb, we may with more justice, though less poetry, declare that the simplicity of the child's understanding dwells on what is unimportant, but commonly passes by unnoticed what is really of moment. The senses, it is true, supply the material—the conscious, or mediate substructure—for the grandest systems of thought; but yet in their further development they must be subject to the action of the culture to which they themselves gave rise. Though at first they were our preceptors, now they are oftentimes our pupils. In seeing we have, perhaps, more need of the understanding than of the eye, just as in walking we could better dispense with strong legs than with sound lungs. The disciplined eye, though of feeble power, descries more objects difficult to be discerned than the strong but unpractised organ. This is true of the microscope and telescope as well as of the naked eye; and the student of Nature to-day, even with the imperfect instruments of his predecessors, sees much more than they. Who is there that has not innumerable times had experience of the dependence of the senses on the understanding, in the fact that, when he is intent on seeing a definite object, his eye becomes almost insensible to all other objects? Thus, one who is searching in a garden for red berries is quite unconscious of the blue berries which stand side by side with the red.

We have in German a term which very happily expresses the faculty, possessed by the most eminent of scientific geniuses, of discovering the important phases of ordinary phenomena: such men are said to have "Blick." Have we not an instance of a higher visual faculty, exalted not only by genius, but also by comprehensive knowledge, when a Gauss was led by the glistening of the windows of a church-tower which he was observing with his telescope to the idea of his heliotrope—an instrument without which no accurate triangulation is nowadays ever thought of; or when a Rittenhouse, in the pretty images seen in a reversed telescope, discovered a means—ever since universally employed—of producing artificial signals which have precisely the same properties as though they stood in infinite distance; or when a Newton made of the spectrum, a thing that had been gaped at as a mere curiosity a thousand times before, the foundation of modern optics?

The sudden arrival at a truth from all sides—a thing so frequent in the history of the sciences, which often makes it hard to decide to whom the honor of new discoveries properly belongs—of itself shows that cultivated minds in general have grasped the idea. The human race might be compared to a traveler in unexplored countries. As the booty he brings home is rich in proportion to the extent of his own intellectual acquirements, which enable him to distinguish what is new from what is hackneyed, so mankind has need of schooling in order to understand what is of importance in the events occurring round about. In short, one must be impressible in order to be impressed.

Ever since the fourth century of our era, the Chinese have used the magnetic needle as a nautical instrument, and thus were enabled to extend their voyages as far as India and Eastern Africa. The Arabians brought us into relations with India in the eighth century, and the Crusaders with the Orient in the tenth, and yet the mariner's compass was not introduced into Europe till the twelfth century.

Does it not seem wellnigh incredible that we cannot trace the use of the free-hanging plummet, as a means of observation, farther back than the period when the Arabians were our teachers in astronomy; nay, that only in the fifteenth century it found general acceptance by the exertions of our renowned countryman Georg von Peuerbach?

When, at the beginning of the last century, Amontons worked with entire success an optical telegraph; and Franklin, fifty years later, robbed the clouds of their lightning; and when both of these men were dismissed even by a learned body like the Paris Academy with stale witticisms; if for thousands of years countless aërolites have been seen to fall to the earth without ever giving rise to an inquiry as to the nature of meteors—the reason is always to be found in the self-same indisposition to receive what is new, which caused mediæval Europe to pass by unnoticed the golden teachings of a Roger Bacon or of a Leonardo da Vinci. Both of these stood high above Francis Bacon as inductive philosophers; but he had for his contemporaries men who had been taught by Copernicus, Galileo, Kepler, and others, some of the mighty consequences of that principle which Francis Bacon had now simply to formulate in order to have it universally accepted. Here and there other eminent men had, long before Roger Bacon himself, hit on the right way of investigating Nature. This assertion, too, rests on unquestionable evidence, which, however, is perhaps not so familiar to you. The visibility of the crescent moon after new moon is of ritual significance to the Jews, the ecclesiastical commencement of their months depending upon it. Their great philosopher, Maimonides, who wrote in the twelfth century, informs us of the process whereby they for a long time noted the moments wherein the lunula became visible; hence they deduced a formula by the aid of which the time of the visibility of the crescent may be calculated. This is induction pure and simple; but not till long afterward was the soil fitted to receive such seed, or the significance of this process recognized.

For only a little over a hundred years have we been following the right path. We have enlarged the capacities of our organs to an extraordinary degree; we have learned to warn our senses of the veils with which preconceived philosophical ideas were wont to blindfold them; we prize the good-fortune which places in our hands any important clew to the working of Nature; disdainful skepticism, of which Alexander von Humboldt says that, in individual instances, it is almost more harmful than unquestioning credulousness, is like the latter disappearing from among us. But we must guard against the error of supposing that herein is our entire salvation. "The educated man is more than a virtuoso, than a specialist; his power does not lie in the exercise of one faculty alone. . . . The man who harmoniously combines within himself the largest number of diverse faculties is a leader of men, though he be surpassed by others in the development of individual faculties. Here we have the fruits of true humanism, of true culture, which is ever aiming at the establishing of an inward equilibrium in the individual as in the state." These words of a renowned poet of the present age foreshadow the counsel I would offer to you for your guidance through life. While, on the one hand, the principle of the division of labor, without which human progress is inconceivable, restricts the functions of the individual within a comparatively narrow province: on the other hand, he only can wisely elect to labor in such a province, and can work the field profitably, who does not lack comprehensiveness. There is no science which has not its æsthetic side, as there is no study of form which may not be advanced by having a basis in fact. Philologists and historians of late have been desirous of having their studies classed among inductive sciences; the investigator of Nature feels more and more every day that he has, perhaps, too long neglected the deductive method. And philosophy itself, the science of sciences, can it subsist without a fundamental knowledge of the grounds of all the sciences? Without philosophy any high degree of intellectual development, in any direction whatever, is inconceivable. Even they who turn away with contempt from Philosophy are, in spite of themselves, compelled to have recourse to her. She alone brings clearness in thoughts upon the nature of one's chosen pursuit—thoughts from which there is no escape for whoever thinks!

Let it then be your firm resolve, students of the high-school *par excellence*, not to attend the lectures simply of one faculty, or of one branch of a faculty. Be true to the principles of a *universitas literarum*. Over and above the studies special to your future calling, do not fail to acquire as liberal an education as possible. Postpone purely specialist studies to the time when you will not only have to receive, but also to give—to produce. Hold in high esteem the ancients in all things wherein they were and still are our teachers. Despise not your less remote predecessors and your contemporaries the world over in matters wherein they alone are the authorities.

# THE SPONTANEOUS-GENERATION CONTROVERSY.

By Rev. W. H. DALLINGER, V. P. R. M. S.

IN the present position of biological science in relation to this important and interesting question, any positive results which have a definite bearing on the difficulties of the subject, and point hopefully to new methods of research, must be warmly welcomed. Prof. Tyndall's beautiful series of experiments "On the Optical Deportment of the Atmosphere in Reference to the Phenomena of Putrefaction and Infection" are precisely of this class, and will give new impulse and direction to all unbiased labor. It is to be regretted when, in a matter so purely one of rigid science as this is, impassioned controversy is suffered to have any place. It fails utterly of its intended purpose, and simply hinders and delays the final issue. There are few but will have admired the animation, courage, and resolution, manifested by Dr. Bastian in the discussion of this question during the last five years; but those who have been most capable of understanding the method, nature, and objects of his experiments, and the general drift of his reasoning, are those who most earnestly disavow the perhaps unconscious, but nevertheless too palpable, advocacy of a *thesis* which his writings so freely display.

Dr. Bastian's position in relation to the origin of minute organic forms has, at the outset, the immense disadvantage of being adverse to the whole analogical teaching of Nature, down to the uttermost depths of minuteness, *where our knowledge is accurate and sound.* Wherever science has put down the landmarks of possession, and is not dealing with the disputable territory of hypothesis, it is absolutely known that at some period in the cycle of development the lowliest organisms are dependent for their propagation upon what we can only look upon as genetic products.

Manifestly, then, it must be weighty—nay, unequivocal and even irresistible—evidence that will induce the philosophical biologist to conclude that Nature's otherwise universal method is changed, in the outmost fringe of organized being. Mere reasoning could never accomplish this. It must be hard, defiant fact, which none can gainsay. But verily no such facts—nor even their most distant forecasts—are before us. The profound difficulties which bristle round the inquiry on every hand are prominent signals for caution; while the uncertainty and incompetency of the methods hitherto employed, and their conflict of results, is alive with meaning. Indeed, we are dealing with organisms so minute as to elude all but our best optical appliances; and the accurate and correct interpretation of the details they enable us to discover requires the practice and experience of years. Of the developmental history of these organisms themselves, we know from actual observation almost nothing with certainty; and the little we do know from such careful and patient observers as Cohn, Billroth, Ray, Lankester, and others, is so complex and conflicting as to demonstrate the necessity of years of patient experiment and skilled research, and to plainly tell us of our ignorance of this minute and wonderful group of organic forms. And yet, forsooth, we are asked, upon the conflicting testimony of a multiplicity of boiled infusions, yielding often even in the same hands uncertain results, and in different hands conflicting ones, to believe that organic Nature—whose method of reproduction is the same to the very limits of *certain* knowledge—changes its method in this uncertain and cloudy region.

Of course, to "spontaneous generation" as a mode of vital reproduction there can be no *a priori* objection. Let us have it by all means, if it be a fact in Nature; but not on any other terms. Is it reasonable to suppose that such men as Darwin, and Huxley, and Tyndall, and Burdon-Sanderson, and Cohn, and Billroth, and Lankester, would shrink from "spontaneous generation" because of the "consequences" to which, strangely enough, it is by some supposed to lead? The very thought admits of nothing but ridicule. And yet Dr. Bastian is displeased with Darwin [1] because he has not definitely determined whether all living things originated in one primordial germ, or originated spontaneously in multitudinous centres scattered over the earth's surface. Both Huxley and Tyndall are in effect charged with grave inconsistency,[2] because, while they admit the origin of all vital forms by evolution, they yet declare that they have never *seen* an instance of "spontaneous generation" of organized forms. It is asked, "Why should men of such acknowledged eminence in matters of philosophy and science as Mr. Herbert Spencer and Prof. Huxley promulgate a notion which seems to involve an arbitrary infringement of the uniformity of Nature?" I dare not answer for them; but for myself I answer, Because the facts as presented to them on the subject—as well known to them as to Dr. Bastian, and we may venture to say as well considered—do not appear

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[1] "Evolution and the Origin of Life," pp. 13–17.

[2] Ibid., pp. 15, 16.

to involve the "arbitrary infringement" of Nature's uniformity of which Dr. Bastian speaks. If these admittedly competent and proverbially fearless men could be led by facts to see that their teaching promulgated an "arbitrary infringement" of Nature's method, is it rational to suppose that they would persist in it another hour? The very position, therefore, of the leading biologists of the day in relation to the hypothesis of "spontaneous generation," is an authoritative declaration of the invalidity of the data on which it rests.

To Dr. Bastian, nevertheless, the "facts," such as they are, have carried a different conviction. But, on analysis, that conviction is evidently not wholly formed upon the bare "facts." It is influenced and stimulated by a "philosophy" which, in short, is this: Continuity in Nature is the grand outcome of all modern research; but if you are to have this in a sense wide enough to include the organic world, you must have "spontaneous generation." Give up this, and continuous evolution is impossible; *therefore* abiogenesis *must* be a great truth.

Of course, continuity in Nature is a profound truth. Every careful and comprehensive student of modern biology will admit that. By Dr. Bastian's own showing, Huxley, Darwin, and Spencer, are its most competent expositors. But they prefer not to be hasty. They decline to determine the exact manner or line of that continuity *until they have facts of a competent kind to guide them.* There may be lines of continuity infinitely more subtile than any the subtilest minds have even conceived. At least they decline to accept one, laid down, as it appears to them, not by Nature, but by Dr. Bastian; and no believer in the evolution of living things, surely, is recreant of his creed who declines a similar surrender.

The largest difficulty surrounding the question of the mode of origin of septic organisms is that of discovering their life-cycle. By dealing with them in aggregations we run told and untold risks. The conflict of results by this means, in the most accomplished hands, employing the most refined methods during the past eighteen years, is a sufficient witness. Repetitions of experiments, and conflicting results, and explanations of the reason why; and so the cycle rolls. Of course, important lessons in biology are learned, but not *the* lesson. And yet by the teachings of this complex and doubtful method *alone* Dr. Bastian is content to accept "abiogenesis" as a great fact in Nature.

To those who are best acquainted with the experimental history of the subject for the last twenty—but certainly for the last six—years this is the more remarkable. For the weight of evidence is certainly not only *not* in favor of "abiogenesis," but is in the strongest sense adverse to it. The most refined, delicate, and continuous researches all point to the existence of what are at present ultra-miscroscopic germs. This, indeed, is directly affirmed by the authors. A single and recent instance will suffice. After a remarkable series of experiments detailed before the Royal Society, Dr. W. Roberts says: "The issue of the foregoing inquiry has been to confirm in the fullest manner the main propositions of the panspermic theory, and to establish the conclusion that *bacteria* and *torulæ*, when they do not proceed from visible parents like themselves, originate from invisible germs floating in the surrounding aërial and aqueous media."[1]

But, further, this has been remarkably sustained by analogical evidence. There are putrefactive organisms that closely approximate to the bacteria in form, structure, and size. These are the "*monads*," or, as Prof. Huxley doubtless more fitly names them, the *heteromati*.[2] They live side by side with the bacteria in the same putrescent mass, and certainly in the later stages of the disintegration of dead organic matter are the most active and powerful agents. From their greater size they present a more promising field for microscopical research than the bacteria themselves; and the life-history of some of these could be fully mastered. I long since felt that valuable aid might thus be rendered to the discovery of the nature of the bacteria. Armed with the best and most powerful appliances which the modern optician could supply, Dr. J. Drysdale and myself ventured on the work. The results are fully detailed elsewhere.[3] It need only be remarked here that the only hope of success was in *continuous* observation of the same form, in the same drop of fluid, under the highest powers. The secret, therefore, was to find a means of keeping the same drop under examination without evaporation. This we did.[4] The result was, that patient work enabled us to completely unravel

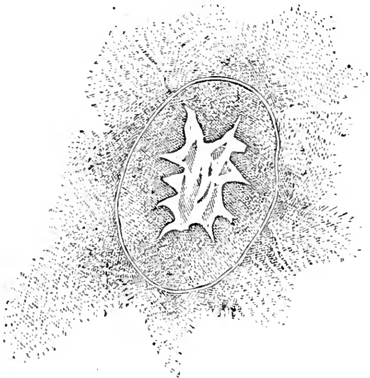

FIG. 1.

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[1] "Philosophical Transactions," 1874, p. 475.

[2] *Macmillan's Magazine*, February, 1876, p. 379.

[3] *Monthly Microscopic Journal*, vols. x.–xiii.

[4] Ibid., vol. xi., pp. 67–69.

the life-history of six of these organisms. These life-cycles cannot be here recounted. Suffice it now to say that each of them multiplied enormously by self-division (fission), but that the life-cycle in *each case* began and ended in *a distinct genetic product*—call them what we choose—spores, germs, or ova.

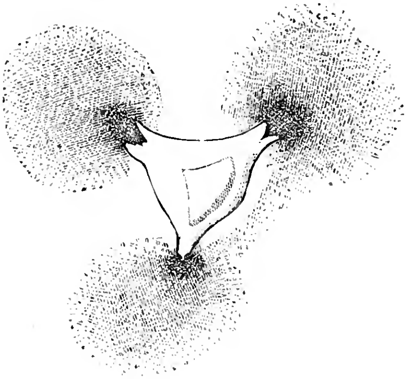

Fig. 2.

I have drawn from Nature, in the six respective cases, the condition presented by each organism at the time of emitting its spores. Fig. 1 is the genetic product of an oval monad, with a pair of *flagella;* it rapidly increased by fission; then in a remarkable manner a pair blended, became *one* in the form of a sac, the sac burst and poured out, as the drawing portrays, innumerable spores, which were watched continuously until they were seen to develop into the parent condition. Fig. 2 gives a similar product of another form, different anatomically and in all the details of metamorphosis, but yet passing through the states of fission, blending into a sac, and (as seen) the emission of spores; which were again watched into the parent con-

Fig. 3.

dition. Fig. 3 shows the direct genetic product of a third, but this sac did not contain spores, but *living young*, which swam forth at once upon the bursting of the sac, and by taking in pabulum at all points of the sarcode rapidly grew to the parent size. In Fig. 4 we have new features. The organism is oval, with one *flagellum*. It multiplies with enormous rapidity by *multiple* fission,[1] and then by distinct genetic union a sac is formed and spores emitted; but they are packed in a glairy fluid, and were so minute that at first our best powers failed to reveal them. But they were afterward seen, and their full development traced. In Figs. 5 and 6 we have the same products of the last two monads. In morphological detail they greatly differed from all the preceding ones, and from each other. But the spore-sacs were produced by the same means, and the exquisitely minute spores poured forth were traced through all their stages to the adult condition.

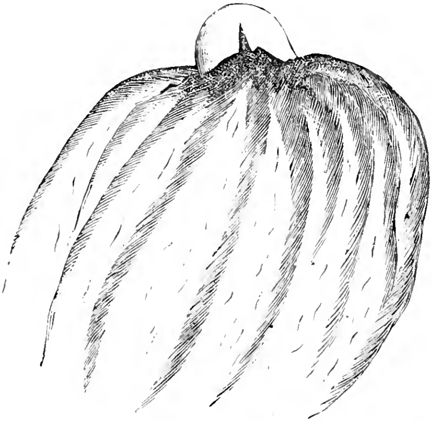

FIG. 4.

We have here, then, important indications of fact concerning the nearest allies of the bacteria: they develop from germs.

We have, besides, the weight of the best experimental evidence pointing clearly to the existence of germs in the bacteria themselves. But the microscope has failed to *demonstrate* the latter. Its finest powers and finest methods failed to reach them.

Happily at this juncture Prof. Tyndall has stepped in, and, with his accustomed brilliance and precision, has opened up the path we need. *He has presented us with a physical demonstration of the existence of immeasurably minute molecules of matter—utterly beyond the reach of the most powerful combination of lenses yet constructed—which are the indispensable precursors of bacteria in sterilized infusions.*[2] In short, he has opened up a new and exact method, which

[1] *Monthly Microscopical Journal*, vol. xi., pp. 69, 70.

[2] *Nature*, January 27, 1876, p. 252; and February 3, p. 268.

must lead to a scientific determination of the existence and nature of the bacteria-germs. His beautiful experiments on the decomposition of vapors, and the formation of actinic clouds by light, led him to experiment on the floating matter of the air, and with what results is widely known. Confined and undisturbed air, however heavily charged with motes, becomes at length, by their deposition, absolutely clear, so that the path of the electric beam is invisible across it. From this, and associated indications, he acutely inferred that "the power of developing life by the air, and its power of scattering light, would be found to go hand in hand;" so that a beam of light sent across the air into which infusions might be placed and examined by the eye, rendered sensitive by darkness, might be utilized with the best results in determining the existence of bacteria-germs. To bring the idea to a practical result a number of chambers were constructed with glass fronts. At two opposite sides facing each other a couple of panes of glass were placed to serve as windows, through which the electric beam might pass. A small door was placed behind, and an ingenious device was arranged to enable a germ-tight pipette to have free lateral, as well as vertical, motion. Connection with the outer air was preserved by means of two narrow tubes inserted air-tight into the top of the chamber. The tubes were bent several times up and down, "so as to intercept and retain the particles carried by such feeble currents as changes of temperature might cause to set in between the outer and the inner air."

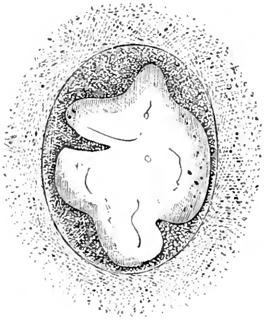

FIG. 5.

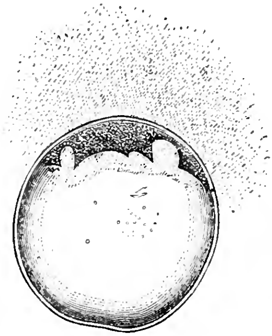

FIG. 6.

Into the bottom of the boxes were fitted large air-tight test-tubes, intended to contain the liquid to be exposed to the action of the moteless air.

"On September 10th the first case of this kind was closed. The passage of a concentrated beam across it showed the air within it to be laden with floating matter. On the 13th it was again examined. Before the beam entered, and after it quitted the case, its track was vivid in the air, but within the case it vanished. Three days quite sufficed to cause all the floating matter to be deposited on the sides and bottom, where it was retained by a coating of glycerine, with which the interior surface of the case had been purposely varnished. The test-tubes were then filled through the pipette, boiled for five minutes in a bath of brine or oil, and abandoned to the action of the moteless air."

In this way the air in its normal condition was freely supplied to the infusions, but of mechanically suspended matter it could be demonstrated that there was none. And it was proved, with a clearness that admits of no quibble, that infusions of every kind, animal or vegetable, were absolutely free from putrefactive organisms. "In no single instance. . . . did the air which had been proved moteless by the searching beam show itself to possess the least power of producing bacterial life or the associated phenomena of putrefaction." But portions of the same infusions exposed to the common air of the Royal Institution Laboratory at a continuous temperature of from 60° to 70° Fahr., fell invariably into putrefaction; and when the tubes containing them amounted to six hundred in number not one of them escaped infection—they were all "infallibly smitten." Here is irresistible evidence that there is a direct relation between a mote-laden atmosphere and bacterial development. The whole series of Dr. Tyndall's exquisite experiments is simply an irrefragable affirmation of this truth. The presence of the physically demonstrated motes is as essential to the production, in a sterilized infusion, of septic organisms, as light is to actinic action. They cannot be made to appear without the precursive motes; they cannot be prevented from appearing if the motes be there. That these are the germs of bacteria by themselves, or associated with minute specks of matter, approximates to certainty in the proportion of hundreds of millions to one.

A beautiful illustration of the minuteness and multitude of the particles is given. Let clean gum-mastic be dissolved in alcohol, and drop it into water; the mastic is precipitated and milkiness is produced. Gradually dilute the alcoholic solution, and a point is reached where the milkiness disappears, and by reflected light the liquid is of a bright cerulean hue. "It is in point of fact the color of the sky, and is due to a similar cause—namely, the scattering of light by particles small in comparison to the size of the waves of light."

Examine this liquid with the highest microscopical power, and it appears as optically clear as distilled water. The mastic-particles are almost infinite in number, and must crowd the entire field of the microscope; but they are as absolutely ultra-microscopic as though they had no existence. I have tested this with an exquisite $\frac{1}{50}$ of Powell and Lealand's, employed with a new and delicate mode of illumination for high powers,[1] and worked up to 15,000 diameters; but not the ghostliest semblance of such particles was seen. But at

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[1] *Vide Monthly Microscopical Journal*, April, 1876.

right angles to a luminous beam passing among these particles in the fluid "they discharge perfectly polarized light. . . . The optical deportment of the floating matter of the air proves it to be composed, in part, of particles of this excessively minute character," and it is among the finest of these ultra-microscopical particles that Prof. Tyndall finds the sources of bacterial life. It is almost impossible to conceive a nearer approach to certainty concerning the nature of these minute particles than this. Their minuteness, their capability of being physically demonstrated, the absolute necessity of their presence to the origination of bacteria in sterilized infusions of any and every kind, taken in connection with what we *know* concerning the germs of the *heteromita* whose life-histories have been studied, render it simply inevitable that we have at length reached, what we are justified in believing to be, a genetic product of the bacteria through which their continuation as organisms is preserved. When first I saw the simplicity and beauty of this method, it struck me that its applicability as a test in reference to germs—*known to be such*—would have considerable collateral weight; and a method of employing it was suggested by a fact in past experience.[1] I had in my possession a maceration of cod's head, which I had kept in use for eleven months. It had become a pulpy mass, and in the middle of January last it was comparatively free from bacteria, but swarmed with two monads—the fourth and sixth of the series described by my colleague and myself. To ascertain their exact condition, I watched them on the "continuous stage" for three consecutive days, and found that both forms were to be seen plentifully emitting spores. The maceration had become very short of moisture, which served my purpose. I subjected it to a drier air with a higher temperature, and it was not very long in becoming a moist pulpy mass, with sufficient cohesiveness to be removed from the vessel; and in this condition it was placed in a heating-chamber, which was slowly raised to a temperature of 150° Fahr., and kept at this for an hour. This was 10° Fahr. higher than Dr. Drysdale and myself had proved necessary to destroy absolutely every adult form. The baked mass now appeared cracked, porous, and flaky. In parts it was extremely friable, and with little pressure crumbled into almost impalpable powder; while by friction a very large proportion was reduced to the finest dust. To avoid all possibility of error this powder was again exposed in the heating-chamber, spread over a plate of glass, to a temperature of 140° Fahr. for ten minutes—thus rendering the plea of mere desiccation impossible.

A chamber or box was now prepared precisely like Prof. Tyndall's, except that there were no tubes to communicate with the outer air.

In the "Researches" on the life-history of monads we had proved that they could live, thrive, and multiply, almost as well in Cohn's "nutritive fluid" as in the normal animal infusion. This fluid is com-

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[1] *Vide Monthly Microscopical Journal*, vol. xii., pp. 262, 263.

posed of phosphate of potash, sulphate of magnesia, triple basic phosphate of lime, tartrate of ammonia, and distilled water. If these ingredients are all mingled the fluid becomes speedily charged with bacteria, unless hermetically sealed, and sometimes even then. We therefore keep the ammonia in a separate solution, mixing them when required.

A portion of the fine dust of the maceration was now taken and thoroughly scattered through the air of the prepared chamber. The condensed beam from an oxyhydrogen lime-light[1] was then sent through it. Its line of passage was far more brilliantly marked inside the chamber than in the outer air. It was deemed inexpedient to insert the fluids while such brilliant points were visible in the air, and four hours were suffered to elapse. The lime-light beam was still visible with perfect distinctness, but its path within the chamber was much less brilliant and more homogeneous than it was without. The fluids were then carefully mixed, and five small glass basins of the mixture were inserted. The whole was undisturbed for five days. At the expiration of that time the beam of the lime-light sent through the chamber was absolutely invisible, although perfectly clear in the open air on both sides of it.

The fluids were now withdrawn. Ten "dips" were taken out of each basin for microscopical examination. *In every "dip"*—that is, fifty in all—*one or other of the monads appeared, and were in a state of active fission;* and in twenty-seven of the "dips" both monads were found. Bacteria swarmed the field, which of course I fully expected.

I now took five *other* glass vessels, and inserted them with great care into the now moteless air of the chamber, and poured in, as before, fresh Cohn's fluid. They were exposed for another five days. On careful microscopical examination of seventy-five "dips" *not a single monad of either form appeared;* bacteria were feebly present, but of course no steps were taken to guard against these, and, as before, they were anticipated.

The air of the chamber was again impregnated with dust, as before suffered for a time to settle, and *these same vessels of fluid*, which had yielded negative results, were again placed in the chamber. At the expiration of five days they were again examined, *and one or other of the monads was found in every successive "dip."*

Now let it be observed that there can be no possible error as to the forms. They were the identical species of the maceration, with which I am as familiar as with a barn-door fowl. What, then, is the logic of these facts? Dr. Tyndall proves that bacteria only develop in sterilized infusions when the air around them is laden with motes of incalculable multitude and exquisite minuteness. Given the pres-

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[1] This was of course very much less capable of "searching" than the electric beam; but it served for the rougher end I had in view.

ence of these, and the development of bacteria is inevitable. The inference is that the motes are *germs*. The above experiments show that, in closely allied septic organisms, the germs of which have been demonstrated and their developments watched, if the dry *débris* of a maceration in which these forms are found be scattered in the air around a prepared fluid, and demonstrated by similar optical means, the said organisms develop; but if the minute dust from the *débris* be optically proved to be *absent*, none of the monad-forms appear. Here we do not hypothecate a germ, but we *know* that it exists; and its deportment in similar conditions is identical with that of the assumed bacterial germ. Do we need more irresistible evidence that the bacteria develop, not *de novo*, but from genetic products?

Evidently Dr. Bastian thinks we do. He tells us in effect that, if Dr. Tyndall has not succeeded, others have, in seeing bacteria reappear in infusions that have been exposed to a boiling-heat for five minutes. This is true; but not to the extent nor with the meaning Dr. Bastian claims. He furnishes a list in *Nature*,[1] for example, of those who are supposed to have secured the results he insists on. But this list is, perhaps hastily, but in effect, most unjustly framed. It is not surprising to see strong protests from the investigators concerned.[2] The citing of Roberts, for example, or Lankester and Pode, or Pasteur or Schwann, is simply a meaningless exercitation to all but the ignorant. Stripped of all disguise, the number of cases of the appearance of bacteria in sealed infusion after five or ten minutes' boiling is few and doubtful indeed. But still there *are* cases, and in one instance at least admirably attested; but they are confessedly exceptional in a high degree. Dr. Bastian, however, prefers to interpret Nature from the exceptional flasks, and infer "spontaneous generation" rather than be guided by the cumulative and overwhelming evidence of the existence of bacterial germs, as the medium of their normal reproduction. This must mean either that he believes that these organisms originate *de novo as well as* by germs, which is a direct *petitio principii;* or else that he is incapable of seeing the force of the facts which render the existence of germs inevitable. From the conflicting evidence of his own writing it would almost appear that he endeavored to maintain *both* these views. He has recently said, "Prof. Tyndall's results, admirable as they may be in themselves, *are altogether collateral, and do not bear upon the main point at issue.*"[3] Surely the "main point at issue" is the mode of origin of bacteria, and we cannot get much nearer the origin of an organic form than by tracing it to a genetic product—a spore! This *was* originally Dr. Bastian's question—did bacteria originate *de novo*, or from parents? It is not so now. He says, "*The* question is, not

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[1] February 10, 1876.

[2] E. G., *Nature*, February 24, 1876, p. 324.

[3] *Times*, January 29, 1876.

what air does or does not contain, since I have long ago shown . . . . that boiled fluids can be made to putrefy and swarm with bacteria in closed flasks, from which air and whatever it may contain has been expelled."[1] The same reasoning also obtains in his communication to the *Lancet*[2] and to *Nature*.[3] The result is clear. The doctrine of "spontaneous generation" rests upon *exceptions* for its truth. In rare instances, and in special infusions, bacteria have appeared after prolonged boiling. After a careful sifting of the evidence, the meagreness of the testimony is striking. All that can be fairly taken at all, when justly weighed, if taken altogether, is not equal to the evidence given by Dr. Burdon-Sanderson.[4] But it is well known that, while admitting and publishing the facts, he ignores absolutely Dr. Bastian's inference. And surely this is the truer philosophy. Let it be granted that, by means not now explicable, the germs of bacteria, destructible in filtered infusions at a boiling temperature, are feebly, and at times, able to survive a slight continuation of the boiling-point in infusions containing solid particles without apparent injury—is not that a ground for inquiring the reason why, rather than for inferring "spontaneous generation?" If we can prove that in ninety-nine cases out of one hundred *actual germs* are destroyed at 212° Fahr., but that, in exceptional circumstances, the remaining one case yields bacteria *after* exposure to 212° Fahr. for some minutes, is not that a reason for inferring, and looking for, some protective influence upon the germ, rather than launching into an hypothesis of a new mode of origin?

That the medium in which minute organic forms are subjected to heat exerts an influence on their subsequent deportment I can abundantly prove. I am equally convinced that the death-point of bacteria-germs hovers very near the boiling-point of water—a conviction amply sustained by fact. This being so, the survival, as germs, of some few, amid incalculable myriads, by some accidental protection, is surely possible. So that, indeed, all true work now should be a study of the *germ* and its properties, and a discovery by patient research of the life-history of the organism.

The valueless nature of mere temperature experiments on such organisms, as tests of their ability to survive, without a knowledge of their life-history, Dr. Bastian, *without knowing it*, has made sufficiently plain. He gives a brilliant illustration—styled by himself "typical"—of the futility of his own method. Consider the facts.

In our "Researches" on the monads, my colleague and myself made it a special point to institute a series of investigations on the points of temperature which the adults, and the spores, of each form studied could resist. The results were as unexpected as they were remarkable. Only the results can here be stated. Taking the spore-

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[1] *Times*, January 29, 1876.

[2] February 5, 1876.

[3] February 10, 1876.

[4] *Nature*, January 9, 1873, vols. vii. and viii.

sacs of the several forms in the order in which our illustration gives them, the data are as follow, viz.: Fig. 1 survived after exposure to 250° Fahr.; Figs. 2 and 4, 300° Fahr.; Fig. 3 (which produced living young), 180° Fahr.; Figs. 5 and 6, 250° Fahr. That is to say, the spore, *after the heating to the above-named temperatures*, were followed step by step until they reached the parent condition. The adults of each form were absolutely destroyed at from 130° to 140° Fahr. Thus, if all the examples be taken together, it will be seen that on the average the spore have a capacity to resist heat better than the adult in the proportion of eleven to six. This is surely important.

Now, until Dr. Bastian's promised "new results"[1] have appeared, I believe I am justified in affirming that the strongest cases on which even he relies for "spontaneous generation" are recorded on pp. 175–180 of his "Evolution and the Origin of Life." They are thus introduced: "After this I may, perhaps, be deemed fully justified in quoting two *very typical* experiments for the further consideration of those who stave off the belief in spontaneous generation—either by relying on insufficient reasons for doubting the influence of boiling water, or because of their following Pasteur, Cohn, and others, in supposing that certain peculiar bacteria-germs are not killed except by a brief exposure to a heat of 227° or 230° Fahr. For even if we could grant them these limits, of what avail would the concession be . . . . in the face of the following experiments?" The details of the experiments follow. They are alike in method, and we will concern ourselves only with the second. A strong infusion of common cress, with a few of the leaves and stalks of the plants, were inclosed in a flask, which was hermetically sealed while the fluid within was boiling. It was then introduced into a digester and gradually heated, and afterward kept at a temperature of 270–275° Fahr. for twenty minutes, and was retained at a temperature, if the time of heating and cooling be considered, over 230° Fahr. for one hour. This flask was opened after nine weeks. The reaction was acid; the odor was not striking. On microscopical examination with a $\frac{1}{12}$-inch objective "*there appeared more than a dozen very active monads.*"

Now, fortunately, Dr. Bastian has not only carefully measured and described these organisms, but he has drawn them, and they are reproduced on the frontispiece of the book. He describes them as the $\frac{1}{4000}$ of an inch in diameter; they were provided with a long, rapidly-moving lash (*flagellum*), by which granules were freely moved about. But, besides this, "*there were many smaller, motionless, tailless spherules, of different sizes, whose body-substances presented a similar appearance to that of the monads*—and of which they were in all probability earlier developmental forms."[2]

Now, by careful comparison, I find that this monad is no other

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[1] *Vide Times*, January 29, 1876.

[2] "Evolution," p. 178.

than the "uniflagellate monad," which is the fourth in the series whose life-histories were studied by Dr. Drysdale and myself.[1] Figs. 7 and 8 will help to make this clear, where Fig. 7 is an exact rendering of Dr. Bastian's monad magnified 800 diameters; and Fig. 8 is a drawing of the "uniflagellate monad" described by my colleague and myself, magnified 2,500 diameters. We describe it thus: "Its exterior form is extremely simple, being ovoid, with a single *flagellum.* Its long diameter never exceeds the $\frac{1}{4000}$ part of an inch" in length.[2] Now, from a very prolonged and careful study of these organisms, I am convinced that Dr. Bastian's form and ours are absolutely identical. But to make the thing simply irresistible we have further and final evidence. One of the metamorphoses of this monad on its passage to multiple fission is that it loses its *flagellum*, and becomes precisely what Dr. Bastian saw all around—a motionless spherule.[3] These little bodies are less in diameter than the active monad, and of precisely the same structure. The identity is thus complete. The evidence is as full as may be; the monad Dr. Bastian saw was the one whose life-history was fully worked out. As usual, it multiplies by fission, but the fission is multiple. It then passes to a sac-like condition, resulting from the uniting together or fusion of two individuals. This sac becomes still and bursts, as seen in Fig. 4, pouring out spores that taxed our highest powers and closest watching. The spores of only two of the monads studied survived after exposure to a temperature of 300° Fahr. *This is one of them.*

FIG. 7.

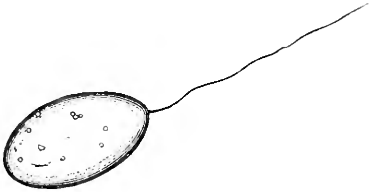

FIG. 8.

Fig. 7, a Monad found by Dr. Bastian in an infusion after heating up to 275° Fahr., said to be spontaneously generated.

Fig. 8, the same Monad as seen by Dallinger and Drysdale, and the spore of which (Fig. 4) survives 300° Fahr.

Now, Dr. Bastian says, "A drop of the fluid containing several of these active monads was placed for about five minutes on a glass slip in a water-oven, maintained at a temperature of 140° Fahr. All the movements of the monads ceased from that time, and they never afterward showed any signs of life."[4] *This is precisely our experience.* But now mark the reasoning. This monad was killed at 140° Fahr., *but it was found in an infusion that had been heated up to* 275° Fahr.; THEREFORE *it must have originated de novo.*

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[1] *Monthly Microscopical Journal*, vol. xi., p. 69, *et seq.*

[2] P. 69, ibid.

[3] P. 69, ibid.

[4] "Evolution and the Origin of Life," p. 179.

But it has been shown that the monad has germs, and that these have a power of resisting heat up to 300° Fahr.—that is to say, 25° Fahr. higher than that to which Dr. Bastian's infusion *was* exposed—and *therefore*, by the logic of facts, the monads found were not a result of "spontaneous generation," *but were the natural outcome of a genetic product contained in the infusion, and which the heat employed could not destroy.*

We need no stronger proof of the futility of reasoning concerning the thermal death-point of a minute organism where developmental history is wholly unknown. Yet so confident is our experimenter of his result that he says: "Nothing that has yet been alleged, by way of objection to the admission of spontaneous generation as an everyday fact, at all affects such experiments as these. The shortest way out of the difficulty would, therefore, be to doubt the facts." But I think I have shown a still shorter way "out of the difficulty," and that without the discourtesy of doubting Dr. Bastian's experimental "facts."

The truth, then, is that Dr. Bastian had no real knowledge of the monad; but he argued as if he had. Hence assumed premises led to a false and fatal conclusion.

He is simply repeating this in his latest attitude in reference to the question of the mode of origin of bacteria. Compelled to yield all else, he throws up a rampart round his exceptional flasks, and declares "spontaneous generation" to be impregnable—an inviolable law of Nature. Dr. Tyndall is plainly told that his knowledge is insufficient, that he has mistaken the meaning of the question, and that his mode of treating it is "laughable;"[1] and all this arises from the fact that Prof. Tyndall dealt with the question of *the mode of origin* of bacteria generally; whereas, to have pleased Dr. Bastian, he ought to have explained some exceptional conditions to which he now points—the exceptions being more important than the rule!

What are the facts?

1. Dr. Tyndall has proved, in connection with a host of others, but in a more definite and precise manner, that in *filtered infusions* five minutes' boiling does kill every form of bacteria.

2. He has further shown that they are propagated by demonstrable germs *only*, in such infusions; and—

3. This fact removes the probability of their spontaneous generation to an almost infinite distance.

As to the development of bacteria in infusions charged with solid matter, precise experiment of a sufficiently comprehensive character has yet to be made on them, in relation to the demonstrated germs. Meantime, shall we accept "spontaneous generation" on such ground as its strongest advocate has now to offer, and ignore the vast chain of facts copiously attested and controlled, which are in perfect har-

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[1] *Lancet*, February 5, 1876, and *British Medical Journal*, February 5, 1876.

mony with the known laws of the entire organic world? This, and nothing less than this, is what Dr. Bastian inculcates and demands.—*Popular Science Review.*

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# SCIENCE IN THE ARGENTINE REPUBLIC.

By Prof. C. GILBERT WHEELER.

MUCH is being done in the Argentine Republic of South America, not only for the advancement of general education, but for the extension of science. The foreign still preponderate over the native workers, yet there is a creditable showing of contributions to science on the part of the indigenous talent of the country. With its universities and colleges, its observatory, Meteorological Bureau, Academy of Science, Argentine Scientific Society, museum, and scientific journals, with its rich and yet little-studied flora and fauna, recent and fossil, the Argentine Republic has large and promising facilities for training scientific investigators, and for vigorous progress in the elements of a higher civilization.

The republic now has, in addition to the considerable number of foreign eminent men of science domiciled within her borders, a few natives, mostly younger men, who are devoting themselves to scientific pursuits. A still larger number are becoming interested in the subject, sufficiently so, at least, to give much time to the collection of specimens, making of experiments, or the recording of observations, besides often expending in connection therewith not inconsiderable sums of money. There is Moreno, the young, bold, and successful explorer of Patagonia; Ramorino, the student of the phenomena exhibited by the famous Rocking-Stone at Tandil; and, as to the supply of careful meteorological observers, our eminent countryman, Dr. B. A. Gould, of the National Observatory and Director of the Meteorological Office, says:

> "There seem to be persons enough who are able and willing to undertake the necessary labor of making systematic observations, troublesome as it is, with no other stimulus than their desire to serve science and their country. In three cases I have found gentlemen who have carried on observations of the sort during past years (up to eighteen), unaided and unencouraged. These have cordially offered me all their data, gratified at seeing their labors appreciated last. I think this young nation, so long struggling with foreign enemies and internal dissensions, has reason to be proud of the number, relatively large, even though intrinsically small, who are ready to work for her welfare and honor, without hope of personal glory or emolument."

Buenos Ayres, "the Athens of South America," has a scientific society denominated "La Sociedad Científica Argentina," with ninety-four active members, mostly natives, although the president is a

Scotchman, the distinguished chemist, Prof. J. J. J. Kyle. Like all similar societies with us, it has had an ebb-and-flow experience, and, judging from the annual report for 1875, now before me, the monthly *séances* in that year were not prolific in scientific memoirs.

The regular monthly meeting, which should have been recently held, was transformed into an excursion to the steamboat-landing to welcome the daring explorer, Moreno, a member of the society, and who had just returned from a long and hazardous expedition, made without companions, and for scientific purposes, in the wilds of Patagonia. The society turned out in strong force, and, accompanied by many other friends and admirers of the "Livingstone of South America," as he has been called, proceeded to the pier, where a scene of enthusiastic embracing ensued, which I imagine must have been serious to one with a less firm *physique* than that of Moreno. Thereupon the noisy, good-humored throng accompanied him to his home, where a repast was served. The society has in contemplation a public dinner to the explorer, at which it is probable he will give some information as to his experiences and the scientific results he has gathered.

The rooms of the society are central, very comfortable, and well supplied with scientific periodicals. There are seven hundred books in the library.

The society offers prizes of a gold medal, suitably engraved, to be given as rewards for the satisfactory solution of scientific problems. These were for 1875:

1. The most important applications of chemistry to the industries of the country.
2. The most important applications of physics to national public works.
3. The best method of utilizing the raw materials of the country.
4. The best material for general construction suited to the republic.
5. The best method of manufacturing materials of construction.
6. The best work on physico-natural science, or its industrial applications.
7. The best work on exact science, or its applications.

The awards for the previous year were:

LUIS GARDELLA. For a steam-engine with multiple boiler.

CONRAD FORRER. For an electric clock.

M. PUIGGARI. Memoir on the manufacture of sulphuric from the raw materials of the country.

JULIUS LACROZE. Memoir upon the utilization of the hard woods of the country in the pavement of Buenos Ayres.

VINCENT GAETANI. For the manufacture in the republic of artificial marble.

It appears to be the custom, on the 28th of July, to celebrate the anniversary of the society by a *conversazione*, at which ladies are also present. An exhibition of objects of scientific interest was this year displayed on that occasion, and proved to be a very interesting feature.

The *Academy of Sciences* is formed from the scientific faculty of the National University at Córdoba, with the addition of other men of science in various parts of the country. The eminent zoölogist, Dr. Burmeister, of Buenos Ayres, is at the head of the Academy, and the members of the scientific faculty of the university are in the anomalous relation of being under the direction of the Academy rather than the university in their duties to the latter.

The secretary of the Academy is at Córdoba, his office being in the buildings of the university, where are also located the scientific collections of the Academy. These consist of:

1. The Mineralogical Museum, containing a rich and very well arranged collection of minerals, altogether the best in the country. The Argentine minerals are particularly well represented and classified according to provinces. There are microscopic preparations accompanying many of the respective minerals and rocks. The collection occupies two rooms.

2. The Botanical Collection is crowded into a room about thirty-six by twelve feet, and entirely too small to admit of appropriately arranging the numerous and interesting specimens.

3. The Zoölogical Collection, which in condition of specimens and lack of arrangement is a disgrace to the curator of this department.

4. The Physical Cabinet occupies three rooms and is a large and quite well arranged collection of apparatus.

5. The Chemical Laboratory is in two of the basement-rooms, one of which is very large. It is well equipped, but the apparatus is not kept in the best order, nor the library which appertains to this department.

6. The Library of the Academy is separated into sections, and the books distributed in the various rooms, where are located the various collections appertaining to the sciences of which they severally treat.

It is proposed soon to rearrange the collections of the Academy, put them in order so far as they are in need of it, and, where requisite, move them into more desirable and commodious apartments. They will, however, remain as now, the material for scientific illustration of the National University courses of instruction.

The glory of the Argentine Republic in the direction of work accomplished for science, and, as far as I am informed, of South America as well, is the National Museum at Buenos Ayres, of which the distinguished zoölogist, Dr. Burmeister, whose reputation is European as well as American, is the director. To a man of science this museum offers as great attractions as any of the leading ones in Europe, and there are many specimens found here, particularly in the department of paleontology, that are entirely unique. Remains of the huge animals of the sloth and armadillo families have nowhere been found so abundantly as in the valley of the Plate; in fact, most are unknown in other parts of the world. The National Museum at Buenos Ayres has a collection especially of Glyptodons and Megatheriums unequaled by any museum in the world; has, indeed, of the former a greater number than are to be found in all other collections. These fossils, found in the Argentine Republic, are objects of special legislation, inasmuch as Congress has by law forbidden their exportation except with the consent of the director of the museum. This consent is given only in those cases where duplicates equally good and interesting are already in the museum. Dr. Burmeister informs me that there are but three specimens of the Glyptodon anything like complete in European museums, and that in the United States he believes there are none. Even those which are in Europe are imperfect in some important features; none of them, for instance, showing the interesting annular connections between the carapace and the base of the tail, thus very much marring the symmetrical appearance which the fossil in reality possesses. The Glyptodon, as will be remembered, is one of the most conspicuous objects in the collection of casts of fossils made at Rochester, and now found in several American museums.

During my stay in Buenos Ayres there has been exhumed a more perfect Glyptodon than any yet in foreign museums, and, as Prof. Burmeister has the same species, I have bought it and shall bring it to the United States.

Besides the remains of extinct animals, the National Museum is rich in specimens of recent fauna, particularly insects. It also contains many objects of archæological and historical interest. Its mineralogical collection is of very trifling importance.

At present the museum appears to be overfilled, and it is evident that larger accommodations than the present are very much needed.

Dr. Burmeister has published the *Anales del Museo Público* now for a number of years, which contains excellent and detailed descriptions of many new species, the originals of which are in the museum. In this work the huge edentates and other mammalia which have made this museum so famous are described and figured.

Scientific Journals in Buenos Ayres.—In 1873 there was published a journal devoted to science, denominated *El Ateno Argentino*. It, however, expired, after six numbers had appeared. It was, I believe, a monthly.

The following year in May the *Anales Científicos Argentinos* was begun as a scientific monthly, of about thirty-two pages each number. The copy now before me contains about twenty pages of original investigation, the balance *excerpta* and translations. Five numbers of this journal appeared when the Mitré revolution, which for the time being paralyzed so many undertakings, extinguished also this laudable private enterprise.

A few months ago the Sociedad Científica Argentina, of which I have already spoken, commenced the publication of a monthly journal entitled *Anales de la Sociedad Científica Argentina*, which appears to be a creditable periodical, and I trust will live and prosper.

There is also published in Buenos Ayres a semi-scientific journal, called the *Anales de la Sociedad Rural Argentina.*

That there is some taste among the general public for scientific reading is exhibited by the circumstance that the daily papers find it worth their while to frequently admit scientific articles.

THE NATIONAL OBSERVATORY AT CÓRDOBA was established in 1872, under the Sarmiento administration, our distinguished fellow-countryman, Dr. B. A. Gould, being placed in charge as director, which position he still holds. The observatory has done splendid work for science since its establishment. A series of maps of the heavens, from the pole to several degrees north of the equator, is in course of preparation under the title "Uranometria Argentina." It is expected to contain about 85,000 stars, 35,000 of which are now for the first time corrrectly mapped. It is far advanced, and will be a monumental work when completed.

A meteorological office is also under Dr. Gould's supervision, and it is intended, when the arrangements now under way are completed, that the Argentine Republic shall also have her "Old Probabilities."

There is a school of mines in the republic, also two schools of agriculture. They, however, are too recently established to admit as yet of important results in their respective spheres.

BUENOS AYRES, *March*, 1876.

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# AMERICAN COLLEGES *VERSUS* AMERICAN SCIENCE.

BY F. W. CLARKE, S. B.,
PROFESSOR OF PHYSICS AND CHEMISTRY IN THE UNIVERSITY OF CINCINNATI.

AMERICA, when compared with other first-class nations, occupies a low position in science. For every research published in our country, at least fifty appear elsewhere. England, France, Germany, Austria, Russia, Italy, and Sweden, outrank us as producers of knowledge. Our original investigators in any department of learning may almost be counted on the fingers. Fifteen or twenty chemists and physicists, as many mathematicians and astronomers, and a somewhat larger number of zoölogists, entomologists, botanists, and geologists, would fill out our meagre catalogue. Among these few discoverers a comparatively small proportion are of high rank. There may be in the United States, all told, twenty men of really notable scientific standing, although there is no one to compare in actual achievements with Sir William Thomson, Helmholtz, or Regnault. In geology we make a pretty fair showing, perhaps, because of the great facilities for research offered by our surveys and exploring expeditions. The newness of our country has also been of advantage to our zoölogists, who have not failed to improve their opportunities. But in chemistry and physics, the two sciences most intimately connected with our greater industries, we have accomplished very little.

Several causes have combined to bring about this state of affairs. There is native ability enough in America to carry on work of the highest order, but inducements and opportunities have been lacking. The labor of developing new regions, of building up commerce, manufactures, and agriculture, of constructing railroads, bridges, and telegraphs, has diverted public attention from matters apparently of a more abstract and less immediately practical character. Material necessities have taken a natural precedence of intellectual wants. Now, having laid our foundations, we begin to think seriously about the future superstructure.

But apart from all these drawbacks to American scientific growth, there is yet another of almost equal magnitude. This is to be found in the system (or rather lack of system) which has shaped our higher education. Our country is dotted over with a multitude of so-called colleges and universities, which have sprung up, not in response to any well-defined necessity, not under the developing influence of broad and clear ideas, generous culture, and wise motives, but because of personal ambition, sectarian jealousy, or petty local pride. States have conferred charters almost indiscriminately, without reason or forethought. Any body of trustees, no matter how ignorant or how foolish, has had but to ask for university powers, and the request has been granted. Incapacity on their part, or injudiciousness in their plans, has seemed to offer no impediments. This policy may be democratic, but it certainly is not wise. Its chief result must invariably be to degrade the standard of education. A college or university charter should be issued only with extreme care, and to fully responsible persons. It ought to demand compliance with certain rigid conditions, and should be forfeited whenever the institution holding it falls below the proper standards. But the mischief has been done, and science has suffered. Let us see how.

In order that science may flourish in any community, several things are needful. There must be a general appreciation of its true value to the world, a clear understanding by men of culture as to the best means for its promotion, facilities for both study and research, and suitable inducements to attract intellectual labor. No matter how able and enthusiastic an investigator may be, he can do little without apparatus or specimens, encouragement, and the means of support. Indeed, the last-named, or bread-and-butter element, is a very important feature of the problem. The human brain is a marketable commodity, at the service of the best-paying master. Payment may come partly in the shape of fame, but something of a decidedly material nature is demanded also. A man may love science devotedly, and yet be starved into adopting some more lucrative profession.

Suppose, now, that a young man of culture, genius, and enthusiasm, wishes to devote his life to science. He has received the necessary training in his favorite branch, and simply asks for an opportunity to apply his attainments both to bodily support and to the extension of human knowledge. At the very start the chances are against him. Many such men are annually driven by necessity out of the field of science, and forced to seek a maintenance in trade, manufactures, or some other department of industry. That a great deal of valuable talent is thus wasted, and turned into channels unsuited to its development, there can be no doubt. That so much good work has been done in a society where so much is lost, speaks well for the human intellect, and shows that real ability is commoner than the majority of people suppose. If seed never fell by the wayside, but only in fruitful places, our views of human nature would soon undergo a wonderful change.

But in the case of our particular novice, employment is at last secured as "Professor of Natural Science" in an average American college. In fact, scarcely any other career would be open to him. Now, how many of the requisites for success are likely to be at his command?

To begin with, he encounters a board of trustees among whom not one has the remotest idea of what science is, or what is essential to its growth. He is called upon by these gentlemen to "teach" chemistry, physics, astronomy, botany, zoölogy, mineralogy, geology, physiology, and perhaps Paley's evidences on top of all. For study and research he has neither time, books, nor apparatus. For study, indeed, he is not supposed to need any time; and if he should press this necessity upon his employers, he would probably be told that he ought to know his lessons before attempting to teach. His students come to him miserably prepared, caring little for what he considers important, and regarding his instruction as so much of an impediment between them and their degrees. And for all this he may receive less than a thousand dollars a year, and that with a feeling of precariousness and uncertainty. At last one of three things happens: he is either called to a chair in some respectable institution, gives up teaching altogether for another less annoying occupation, or else, his enthusiasm quenched and his aspirations gone, settles down into a dreary rut, to rust out the remainder of his days.

This picture may seem exaggerated, and yet it is wholly within bounds. Many men have been ground through the mill of an unendowed country college professorship, and know how hard and thankless were the tasks assigned for them to do. In such a position the true man of science can very rarely find either appreciation, encouragement, facilities, or pecuniary reward. Discouragement of the most wearing kind will, in nine cases out of ten, be his lot.

The American college system, then, is clearly an impediment in the way of American science. It acts adversely in several modes, and these I purpose tracing.

There are to-day in America over five hundred institutions claiming the name of college or university. Of these more than forty are in the single State of Ohio. Some are exclusively for male students, others receive only young ladies, the majority are arranged for the co-education of the sexes. Every religious sect, or fragment of a sect, is represented: Baptists, Free-will Baptists, Seventh-day Baptists, Presbyterians, United Presbyterians, Cumberland Presbyterians, Episcopalians, both High-Church and Low-Church, Methodists of divers complexions, Adventists, Swedenborgians, Friends, Unitarians, and Universalists: all control special institutions, equipped and endowed with due reference to the perpetuation of sound faith, and, incidentally, to the encouragement of what is supposed to be learning. Among Catholics, who now control seventy-four colleges, the inter-sectarian character is strongly marked, and institutions are recognized as especially Jesuit, or Franciscan, or Benedictine, or managed by the Christian Brothers, or by the Congregation of the Sacred Heart.

Now, there are several ways by which this sectarianism in education works mischief to science. The very fact that a college has been established for theological purposes, or for ecclesiastical aggrandizement, is adverse to good scientific research. Even though the teacher of science may not be directly hindered, the studies which are of especial value to theological students will be given undue prominence. In fact, nearly every American college emphasizes the classics and literary studies, and looks upon natural science as something of minor importance, often as a dangerous accessory, which must be tolerated, but not encouraged. A college catalogue which now lies open before me, after announcing that full provision has been made in its course for the inculcation of religion and morality, asserts that "scientific culture is of value only in so far as it is based on a true conception of God, and our relation to him." Such a statement as this, viewed from the standpoint of any particular sect, will usually be found to mean more than the mere words indicate.

But the great injury to science is done by the unnecessary subdivision of forces. Forty institutions spring up where only one is needed, and nearly all of them are necessarily weaklings. Libraries, cabinets, apparatus, buildings, and faculties, are foolishly duplicated. Each college lives in a continual struggle for existence, doing inferior work, and paying miserable salaries to an inadequate corps of teachers. If there were such things as Presbyterian mathematics, Baptist chemistry, Episcopalian classics, and Methodist geology, such a scattering of educational forces would be pardonable; but, as matters really stand, it is a nuisance for which no valid excuse can be found. Here there seems to be a real conflict, not between religion and science, but between the injudiciousness of religious people and the requirements of scientific research. Where one good laboratory should exist, we have forty small and inferior sets of apparatus, each fit only for elementary instruction, and wholly unsuited to purposes of investigation. Thus the very institutions which we should naturally expect to advance science have been made by sectarian spirit incapable of yielding solid results. Other branches of learning suffer also, only science is most impeded of all. The classics, mathematics, philosophy, or literature, demand few appliances. Give the professors a fair library, perhaps some maps or charts, and a recitation or lecture room apiece, and all is provided for. But science, to be properly taught, demands much more. There must be not only laboratories and apparatus, but material and specimens; and these all cost much money. No wonder, then, that a poor institution cramps its scientific teachers, and offers meagre opportunities for the prosecution of their best and most valuable work.

Going a step beyond this curtailment of material means, we shall find that the division of forces again operates contrary to science in the selection of professors. In the first place, poverty compels a college to demand more work from a professor than any man can well do. A teacher who is called upon to instruct elementary students in half a dozen distinct branches cannot accomplish much real work in any one. Every branch of science is vigorously growing, and can be properly taught only by one who has the time to keep abreast of its growth. A large majority of American college professors are now incompetent, because the policy of college management keeps them so. Let us glance at a few of the professorships which some country colleges have established. Here, for example, is McCorkle College, situated in Eastern Ohio, whose ministerial president is "Professor of Hebrew, Natural, Mental, and Moral Science." Surely this gentleman, if his professions are honest, must be the most learned scholar in the world. His "moral science" would, of course, prevent him from undertaking any work which he was incompetent to do. We cannot suspect a "reverend" of hypocrisy in such a matter as this. In Maryland, New Windsor College contrives to neutralize scientific heterodoxy with a "Professor of Abstruse Science and Religious Instructor." Such a teacher can easily take time by the forelock, and inoculate the minds of his young charges with a proper disrespect for the awful notions of Darwin, Tyndall, Huxley, Draper, and company. Another Maryland college, St. John's, rejoices in a "Professor of Natural Philosophy, Chemistry, Mineralogy, and Geology, and Lecturer on Zoölogy and Botany." Penn College, in Iowa, has a "Professor of Natural Science and Political Economy;" and Eminence College, Kentucky, a "Professor of Biblical Literature, Mental Philosophy, and Chemistry." Even in New York State there is Hobart College, with its "Professor of Civil Engineering and Chemistry, and acting-Professor of Mathematics and Modern Languages." Professorships like these are by no means rare; they are the rule rather than the exception. A very large majority of our so-called "institutions of learning" employ Jacks-of-all-trades to do the work of instruction, and how well that work is likely to be done we can easily imagine; indeed, it is difficult to understand how a conscientious man can undertake such tasks. Every teacher who is competent to teach at all must know that he is unable to cover so much ground, and should refuse to be a party to such fraudulent teaching. Fraudulent is not too strong a word to use in this connection. An institution which receives money from its students in payment for an education such as it cannot give, is certainly guilty of fraud. These frauds are the natural outgrowth of improperly-granted charters, incompetent or ignorant boards of trustees, and reckless sectarian pride. Every denomination seems to be imbued with the characteristic American anxiety for display, and the establishment of a new college is a convenient piece of clap-trap to resort to. Surely the advancement of religion ought not to render necessary such sacrifices of true principle! If false pretensions are to be thus directly encouraged by the churches, what can we expect from the people at large?

The smaller colleges, however, are not the only ones to blame in this matter of professorships. They are perforce compelled to employ smatterers, because of their inability to pay the proper number of specialists. But institutions of considerable wealth often injure science in their selection of teachers by introducing false issues into the question. Every year professors are chosen, not on account of scientific ability, but for reasons of a theological or sectarian character. If two men, one a Baptist, and the other a Unitarian, were candidates for the same professorship in a Baptist university, the former, even if very much inferior to his rival, would almost certainly be elected. There may be exceptions to this general rule, but they are very rare. Even at Princeton issues of this sort are frequently raised, and the ablest candidates have been rejected on purely dogmatic grounds. Theological soundness in such an institution far outranks scientific ability. If Laplace had lived in America, no college would have tolerated him for an instant. Almost any decayed minister, seeking an asylum, would have beaten him in the race for a professorship. Not many years ago, the ablest chemist America has ever produced was a candidate for the chair of chemistry in a very prominent Eastern college. He did not believe in the Trinity, and for that reason alone failed of an election. The immorality of such a system is manifest. When success or failure is made to depend upon a mere *profession* of belief, a direct premium is put upon hypocrisy. Incompetent men are not unlikely to be unscrupulous also. Science cannot really flourish in America until, in this respect, the colleges mend their ways. Men must be chosen professors because of their fitness to teach specified subjects, and not on account of their notions, real or professed, concerning abstract theological dogmas. Moral character ought, of course, to be considered; but mere speculative belief, never.

Another objectionable result of college scattering is the under-payment of professors. Even our best universities have shortcomings in this respect. A teacher upon small salary is naturally somewhat unsettled in his mind, is apt to be looking about for better employment, and is liable to feel a constantly diminishing interest in his work. Stability of place and freedom from pecuniary anxiety are very important to an investigator; and just these requisites few American colleges are able to supply. A large salary is not absolutely necessary to a scholar, but a certain means of comfortable subsistence is. At present, when wholly inadequate payment is offered, there is scarcely any inducement to attract a young man into the scientific life. A professorship or tutorship may be accepted for a year or two, perhaps, just as a stepping-stone to something more lucrative, but how rarely is the teacher's vocation taken up as a career! Almost every other important occupation yields surer rewards, and a fairer prospect of attaining to a competency. A young lawyer, doctor, or merchant, if careful and industrious, may reasonably look forward to possessing at some time a home of his own, with the means of sustaining and properly educating his children. The young devotee of science, however, has rarely any such possibilities before him. His labor is as arduous as, and demands even more talent than, that of the attorney or physician, but the recompense is vastly less. If, as he ought, he gives his leisure moments to the advancement of learning, he will find his salary insufficient for the maintenance of a family. In order really to live, he must constantly be doing outside work. He will thus struggle along, year after year, in constant danger of being discharged or supplanted, and, in his old age, weary and broken down, will find himself little more than a pauper. Is it strange, then, that the best intellectual talent of America is repelled from professorial positions, and attracted into other fields of labor? Can science be expected to flourish under such a system? We pay mere popular lecturers well enough; and surely the real workers, who create science, ought to be fairly recompensed also. But we can hope for little improvement until the number of colleges is reduced, and the means of those remaining suitably enlarged. Science must offer careers to men of ability, with the rewards which capacity, skill, and faithful industry, always ought to receive.

But, after tracing all the effects produced by the division of educational forces, we shall still find other points in which our college system is prejudicial to science. Glance over the curriculum laid down in almost any college catalogue, and see how the scientific instruction is arranged. In nearly every instance there will be found an enormous disproportion between linguistic studies and science. As a rule, over one-half of a student's time for four years is assigned to language; the remaining half being divided between mathematics, English literature, history, philosophy, and "natural science." Chemistry, for example, is generally taught through a single term (one-third or one-half, as the case may be) of the junior year. Thus a study, extremely important both practically and as a means of culture, is pursued by a student for perhaps three hours a week during one-eighth or one-twelfth of his college course. In some institutions, undoubtedly, more time is given to chemistry; but such cases are comparatively rare. A youth will enter college with at least a year's preparation in Greek, and then will follow that study for the greater part of his four years' course; but the science from whose applications he derives direct benefit every day of his life is crowded out into an obscure corner of the curriculum, and made to seem of little value. Physics is treated like chemistry; while geology, botany, zoölogy, and astronomy, are pushed even closer to the wall.

Now, what effect has this unfair distribution of studies produced upon American science? Plainly, a very bad effect. Our scientific men must be recruited mainly from among the ranks of our college graduates, and hence the latter ought to be imbued with something of the scientific spirit. That spirit is not likely to be very strongly aroused by the present policy of make-believe teaching. In fact, an enthusiasm for science is dampened rather than encouraged in the majority of American universities. The student sees men of fair training employed to teach the classics, while the work in scientific branches is done by wholly-untrained or imperfectly-trained instructors. Frequently it happens that Latin and Greek are taught by separate professors, while a single teacher is called upon to cover all science outside of mathematics. It is easy to see what effect such a state of affairs is liable to produce upon the mind of an average pupil. He becomes accustomed to regard the sciences as comparatively unimportant. He learns almost nothing of their true relations to life, and the little which he does happen to pick up is gleaned from a few superficial lectures and two or three trivial text-books. If he fails in these studies at examination, the failure counts practically nothing against him upon graduating. In short, the college deliberately carries out a policy of scientific smattering, and the student is influenced about as might be expected. He graduates in complete ignorance both of the methods and of the aims of science, having learned only a few disconnected facts concerning the great world about him.

Very many American colleges, however, now provide what claim to be "scientific courses," running for four years parallel with those in classics, and leading to bachelor of science degrees. This fact illustrates only a sham deference to the public demand for less Latin and Greek, and amounts to very little in favor of science. A striking case in point is furnished by McCorkle College, the learned president of which we have already referred to. Let us analyze the course laid down in the catalogue. There are three terms per annum for four years, or twelve terms in all, and in the regular classical course the studies run as follows: Latin is taught during ten terms; Greek, through eight terms; mathematics, five; history, four; Hebrew, three; natural philosophy, two; chemistry, two; geology and astronomy, one each; other studies, mainly philosophical but none scientific, seven. The modern languages seem to be omitted altogether! Then, following the schedule from which this abstract was made, comes the announcement that "the scientific department will embrace all the above course except the classics." Could a more contemptible sham be invented? Would it be possible to do more in the way of belittling science? The total omission of scientific studies would be more honest and more truly in the spirit of science. And yet this institution is empowered to grant degrees, and has the same legal authority as Harvard, Yale, or Cornell. This is, to be sure, an extreme case, but it is not much worse than a host of others. As a general rule, the "scientific course" in a Western college is the classical course, *plus* a little mathematics, and with French and German substituted for Latin and Greek. Less preparation on the part of the student is required to enter it, and every applicant is given to understand that it does not rank quite equally with its older rival. In both courses the natural sciences are similarly arranged, so that the graduated bachelor of science knows really no more chemistry, physics, botany, zoölogy, geology, or astronomy, than the supposably less scientific bachelor of arts. In fact, the great majority of so-called "scientific courses" are mere makeshifts, intended to accommodate those students who are too dull, or too imperfectly prepared for taking the more thoroughly-equipped line of study in the classics. Here, again, American colleges oppose the development of the scientific spirit, and hinder seriously the growth of American science.

It would be possible to multiply indefinitely these illustrations of weakness on the part of our college system. Institution after institution might be cited in which not science only, but all culture, is at the lowest possible ebb. Just the bare facts concerning some Western and Southern colleges would, if published here, seem like incredible exaggerations or distortions of the truth. I have beside me college catalogues which are positively grotesque in their absurdities; no satire could do justice to them. One institution in particular, situated in Tennessee, has fairly reached the point at which the sublime and the ridiculous meet. In respect to science, even some of our oldest and best universities are open to criticism. Some apply theological tests in the election of professors, and in a mild way act toward modern science as some of the Spanish universities once acted toward the discoveries of Newton. Many others make lower standards for scientific than for classical students, seemingly upon the idea that a bachelor of science is expected to know less than a bachelor of arts. Perhaps the scientific spirit is now best represented in this country by the Sheffield Scientific School at New Haven. Here the policy of the institution seems to have been entirely shaped and guided by the Faculty rather than by the trustees. The Lawrence Scientific School did stand higher before the abolition of its special laboratory, and approximated closely to the German idea; but of late its Connecticut rival has passed it in the race. As a university, taken for all in all, Harvard is probably far ahead of Yale, but in training scientific students the latter can at present claim superiority. The Columbia College School of Mines is also a good institution, but it errs in the direction of over-thoroughness. The students have so much routine and detail work to do that no time is left for originality. The instructors, too, are overworked, so that they can accomplish little in the way of research, and they are, moreover, in many cases, underpaid. This latter evil the trustees can and should remedy. It also occurs at Cornell University, and has lost to that institution the services of several valuable men. These points are mentioned now, not hypercritically, but because they serve to illustrate certain discouragements which our scientific men have to encounter.

Now, having recognized some of the weaknesses in our American mode of conducting the work of higher education, we may reasonably ask how they are to be remedied. How shall reform be brought about, and by whom?

It is quite evident that improvement must come partly from within and partly from without. The internal management of each college must modify itself for the better, and its efforts should be strengthened and encouraged by exterior influences. From the latter, however, we have most to hope. As long as our colleges are controlled by men who do not appreciate thoroughness in scientific culture, we can expect but little from within. An incompetent Faculty is not likely to become suddenly conscientious and resign, neither are average boards of trustees prone to confess their incapacity. External pressure must be brought to bear both upon trustees and upon professors before they can be made fully to realize the responsibilities resting upon them. This pressure may come, partly from public sentiment, and partly, though later, through legislation.

But how shall public sentiment be properly shaped and made available for service? How is its natural though slow growth to be fostered and directed? Mainly by the efforts, organized and individual, of scientific men. Personally, every worker in science should strive to awaken in the community about him a comprehension of the value and the purposes of his particular branch. In other words, the real investigators ought to do more toward popularizing their discoveries, instead of leaving the task to amateurs or charlatans. At present, unfortunately, too many able scientific men depreciate popular work and hold aloof from it. They do nothing themselves to interest the general public, and then lament the fact that the public does not become interested. Yet just here is where the beginning must be made. With a wider public interest in science will come a deeper public appreciation, and this will develop the tendencies necessary for the improvement of our colleges and schools. Until the people see and recognize the difference between true investigators and mere collectors of specimens, between original workers and text-book amateurs, little real progress can be made.

Organized effort is also needed. Just as lawyers or physicians band themselves together, so also men of science should combine for mutual self-protection against quackery. A man who had never been admitted to the bar could scarcely be chosen to a law professorship, neither could any one but a regular graduate be elected to teach in a respectable medical school. Why should not organization among chemists, geologists, or naturalists, produce in the long-run a similar state of affairs? Such an effective organization it might be difficult to bring about, and still something could be done. Even a very little improvement would be better than no improvement at all. Local scientific societies might do good in two ways: 1. By preventing, or at least opposing, bad appointments in colleges; 2. By furnishing the means for popular lectures and field-excursions. They could also, perhaps, do something toward breaking up the present vicious and absurd mode of teaching science by mere text-book recitations, and so help forward the adoption of correct methods. An attempt to teach drawing or music by lectures only, would be universally recognized as nonsensical; the same system of instruction applied to any one of the natural sciences is equally ridiculous. Nature must be studied at first hand to be properly understood.

Through legislation also something may be accomplished. This something may be very little, but a good many littles taken together aggregate much. Just as a single dollar may be the beginning of a great fortune, so one apparently trifling measure can become the starting-point of a sweeping reform. The first step to take in this direction is to prevent the issue of more charters. Inflation is as bad in education as it is in finance. No State which already contains more than one fair college or university should permit another to be established. Let the millionaires who wish to help learning give their money to institutions already in existence, or else not give at all. No benefaction is better than a mischievous benefaction. It is not long since Massachusetts lost a splendid opportunity to inaugurate the policy here recommended. The Methodist denomination of that State were discussing the foundation of a new educational institution in or near Boston. Harvard University at once made a very liberal offer; namely, that if the Methodists chose to establish merely a theological school, and to place the same in Cambridge, it would give them rent free the use of a lot of land for their building, and would permit their students to have access to the great library, and to attend, without expense, fifty courses of lectures. This magnificent offer was foolishly declined, and the Methodists founded, only four miles away, the Boston University—a school for which there was no real demand, and which signified merely sectarian folly. If at that time the Massachusetts Legislature had refused to grant a charter, a good move would have been made. The money bequeathed by Isaac Rich might perhaps have gone to the Wesleyan University at Middletown, making that comparatively weak institution really strong. As it was, the Methodist denomination, with more zeal than discretion, divided its forces in New England, started a college within half a dozen miles of at least three others, and contributed heavily toward the perpetuation of the present vicious policy. Tufts College is another wealthy institution close to Harvard, doing little save to adorn a high hill with brick and mortar, and wholly unable to compete with its great rival. All over the country there are to be found similar examples of what is at once multiplication of means and division of forces. Galesburg, Illinois, has two colleges: one Presbyterian, the other Universalist. Nashville rejoices in four: one Methodist Episcopal, another Methodist Episcopal South, a third for colored people, and the fourth vaguely described as "non-sectarian." This senseless scattering of appliances ought never to have been permitted. The true policy is, to establish great central universities, around which as nuclei the theological schools may cluster. A plan of consolidation among existing colleges would be difficult to carry out, but to some such plan we must eventually look for reform.

Perhaps at some future time it may also become possible to regulate colleges by law, and to compel them to maintain certain standards of scholarship. If a few institutions which are now doing sham work should be summarily deprived of their charters, and so rendered unable to confer degrees, much good would result. No Legislature, however, could as yet be induced to take such a step, even supposing it to be perfectly legal. A policy of this kind must follow after the awakening of public sentiment. But the principle that every institution of learning ought to be what it pretends to be, is unquestionable. No kind of fraud is more objectionable than fraud in education.

As a matter of course, legislation upon the college problem would have to be different in different States. Neither Rhode Island nor New Hampshire need act at all upon the question; but Ohio, Indiana, and Illinois, ought to move vigorously. In these and other Western States, especially the States which sustain universities at public expense, a healthy and judicious system of taxation might be desirable.

If every college controlled by a private corporation was energetically taxed, the weaklings would soon be either suppressed entirely or forced to consolidate with other stronger institutions. Ohio alone has at least a dozen colleges which taxation would affect in this way. At present, they are public nuisances; united, they might become a source of public good.

# SOCIAL EXPERIMENTS IN UTAH.

By J. H. BEADLE.

THE social anomaly of Utah is of interest not only to the politician and the philanthropist, but also to the scientific student of society, whose object is simply to find out how the thing works. Though not claiming to be a sociologist, I have had considerable opportunity to observe the operation of social forces among the Mormons, and in this article I wish to present some conclusions that I have formed relating chiefly to the economical aspect of the matter.

Judging from the tone of much of the Eastern press, one might conclude that most thinkers regarded Utah as an exception to the rules which govern other human societies; as we read frequent eulogies on its people and their progress, coupled with innocent wonder that such institutions could have produced such results. It seems to be conceded by these writers that in one part of the world a whole people may be Asiatic in religion and social type, and European in energy and intellect; at the same time going forward in wealth and culture, and backward in intellectual and moral discernment. Facts and figures may show, however, that what we should have looked for, reasoning deductively, is really there, although a little disguised at first. To treat it first in its purely economical aspects, I lay down the broad principle that, in this climate and on this soil, a polygamous community cannot get rich.

For, first, polygamy tends to the multiplication of the helpless, to make the proportion of consumers to producers unnaturally large. The political economist knows that the surplus year by year accumulated in the United States is small compared with the popular idea of it—rarely exceeding three per cent. This, funded and in turn made productive, measures the general increase of wealth. Suppose, now, some factor introduced which should consume this three per cent. of increase: it would result that the people would be pressed down upon the verge of poverty, and wealth would augment no faster than population, perhaps not so fast. Polygamy has just this effect.

True, the children are all the while growing toward the age of self-support (which in the West may be set at eighteen years); and, could all survive, this evil would in time correct itself. But, under ordinary circumstances, forty per cent. of the race die before reaching that age. So of this increase beyond monogamic rates all is a present loss, and forty per cent. an absolute loss. But this is not the worst. The ratio of consumers to producers must in any case vastly increase before any of the young become self-supporting. Hence a much smaller surplus, a smaller ratio to each of what sustains and cheers life, and less to bestow upon the weaker, who have extra needs; consequently a stronger pressure by the whole community on the means of subsistence, a sharper struggle for existence, and a considerably greater mortality among the feeble children. This in turn increases the dead loss set forth above; and thus polygamy causes the loss beyond recovery of a part of the productive energy of a people appreciably greater than is lost in monogamy. This it is, doubtless, which causes much of that large infant-mortality in Utah, which so many have noted, and which has often been mistakenly attributed to the purely physiological effects of polygamy. It is not that children are born with weaker constitutions, but that too many of them are born for the productive strength of the community to carry.

This position will be best appreciated by a comparison with any locality in the Central West—say, a rural region in Ohio. There about one-fifth of the whole community are producers. One-half are children, one-half the remainder women (whom political economy does not consider as producers), and a small proportion infirm and aged. Given freedom, monogamy, and natural conditions, this proportion will maintain itself with almost perfect constancy. There will always be a certain proportion of unmarried women. Families will average four or five children each, and the annual increase will be such as the productive capacity of the Commonwealth can carry, and leave a slight surplus to add to its funded wealth.

Now, introduce polygamy, apportion the single women, and possibly import a few more. Give every fifth man two wives and two sets of children, every tenth man three, and every fiftieth man from four to twenty—this is about the condition in Utah—and what then? In ten years, instead of one-fifth, only one sixth or seventh of the whole population will be producers; and the number of the helpless will be greater than the aggregate strength of the community can provide a proper surplus for. Inevitably, then, the whole population will press harder on the means of subsistence, there will be less abundant nourishment, and a weakening of vitality among the poorest, and, in no long time, a marked increase of mortality among the children thus imperfectly nourished; for thus does inexorable Nature restore the balance with a stern justice untempered by mercy. That Utah polygamy causes more children to be born is unquestioned; whether it would result in a greater permanent increase of the population is very doubtful. It certainly is not true that the polygamous races increase faster than the monogamous; as witness Germans and Turks, Russians and Persians, Britons and Hindoos.

Similarly, polygamy would add from 30,000 to 40,000 children per year to the population of Massachusetts, with no increase whatever in the number of producers. In eighteen years, at least 500,000 non-producers would be added to the Commonwealth. The first result would be, as the pressure slowly increased, that children would be withdrawn from school at an earlier age, and put to severer tasks, women would more and more be forced into the field and workshop, with still a decided increase of poverty. Despite these extra exertions against it, cases of want would greatly multiply; all the weaker constitutions would encounter extra risks, because there would be both extra exactions upon them, and less surplus to provide for their extra wants; and thus the evil temporarily avoided in one direction would come around with redoubled force in another. Where monogamy, legally enforced, possibly prevents the birth of 30,000 children annually, polygamy would in time result in more than 30,000 extra deaths; there would, meantime, be less of average food, clothing, school-books, cheap excursions, and healthful amusements, less of everything that makes life possible or desirable, a decided increase in the aggregate of unhappiness, and still a dead loss in the wealth of the community. That all these results are to be witnessed in Utah is the testimony of travelers of every shade of belief, though Utah is a new country, and free from many of the difficulties which would be met with in Massachusetts.

At this point a side-issue presents itself, which it may be well to consider. My observation in Utah, and comparison with Eastern communities, convince me that there is a certain normal rate of increase, beyond which it is scarcely possible for an Anglo-Saxon community to go; or, if possible, very undesirable. I mean, of course, natural increase, immigration being left out of the account. Settle a new country with nearly equal numbers of the sexes, and the population will increase very rapidly as long as the unappropriated wealth of Nature continues; it will even double, from natural causes alone, every twenty-five years, until most of the land is occupied. Then a noticeable decline in the rate of increase will ensue; and such rate will decrease with almost constant regularity as the population increases. It will be manifest in three ways: people will marry later in life, successively larger numbers will remain unmarried, and the average number of children to each family will be less. The large number of unmarried women in Massachusetts, the considerably smaller number in Indiana, and the very small number in California, are thus seen to be legitimate results of the relative ages of those communities. Of course, new inventions, enabling each producer to get more of the necessaries of life from the same amount of labor, will have a similar effect to that of unappropriated natural wealth, and this enables some of the oldest countries to still maintain a slight increase. But, ultimately, these growing communities must reach a condition in which a very considerable part of the population will remain unmarried.

Is it possible to change any part of this by artificial methods, such as law or preaching, to increase the number of marriages? I think not. And, if it were possible, no matter on what grounds of morality or expediency urged, I firmly believe it would result in a decrease of the average happiness, and ultimately in a social degeneracy. Those philanthropists who lament with such frequency the relative decrease in marriages may justly rest for a season from their jeremiads. It is not the extravagance of women, the selfishness of men, nor yet the ambition of parents and the dissipation of contemporaneous society, that causes the decline. A decided majority of those men who remain single till late in life, or permanently, are among the most prudent and economical, often carrying both qualities to an extreme. "Stingy old bachelor" has passed into a proverb. The single man who follows some legitimate business is filling his place in an old community as well as the married man. He adds one to the producers. From this evil, if it is an evil, there can be no artificial remedy in an old society; it is to be borne as a necessary consequence of the constitution of Nature, and alleviated only by each individual's mental cultivation. This principle may also be modestly commended to those enthusiastic patriots who calculate our probable population in the year 1900. One and all, they expect the percentage of increase to continue the same, which cannot possibly be. It was less from 1860 to 1870 than from 1850 to 1860; and will be still less from 1870 to 1880. The best places are seized upon, and population must now go back and fill up the odd corners left by those who had the first pick of Nature's wealth. The phenomenon of rapidly-growing States, like Illinois and Iowa, will never be witnessed again in this nation; for no such bodies of land are to be found anywhere west of longitude 96°.

It is fitting that I should here notice one powerful corrective to the natural tendency of polygamy in Utah—the non-Mormon population. It now numbers about 15,000, and includes at least four men to one woman. It is customary to divide the people of Utah into two classes, but it should be three: the Orthodox Saints, the "Hickory Mormons," or Liberals, and Gentiles. The second class consists mostly of the native young Mormons, born in the Church, but almost universally freethinkers; for Mormonism in a family never outlasts one generation. The Orthodox may safely be set at 60,000, still more than one-half the whole population—men and women devoted to Brigham Young and the priesthood, and ready to go into polygamy or anything else at his bidding. The "Hickory Mormons" are about half as numerous; and in the various proportions of the sexes between these three classes is the most curious feature of Utah. The Liberals alone are in natural social conditions, men and women being about equal in numbers; while of the Orthodox there are probably five females to four males. It is of course impossible to be numerically exact; but my observations in all the towns of the Territory, and in the mining-camps (Gentile), convince me that the following exhibit is very near the exact truth:

| | | |
|---|---|---|
| Orthodox Saints | males 27,000, | females 33,000 |
| "Hickory Mormons" | " 15,000, | " 15,000 |
| Gentiles | " 12,000, | " 3,000 |
| Total | " 54,000 | " 51,000 |
| Male excess | 3,000 | |

The census of 1870 showed a male excess of 2,056, but the great Gentile increase since that time will make it 3,000, if not more. The above table includes all ages.

Observe how unequal are the social conditions. In a purely Mormon town there is often an evident surplus of women of a marriageable age. In a mining town, such as Alta, Bingham, or Ophir, there is a distressing scarcity. In one such town of my acquaintance with 1,000 inhabitants there are barely children enough for a small school, and not women enough to form a sewing-circle! Throughout the Territory the mining towns (Gentile) are some distance up in the mountains, while all the agricultural settlements (Mormon) are necessarily in the valleys. Seeing that human nature is what it is, whether the grand passion be regarded from the moral or merely physical standpoint, one might conclude that the mountaineers would descend upon the valley towns and repeat in more modern style the epic of unwived Rome and the Sabines. This has been prevented by the lack of social intercourse between the two classes, and still more by the vast differences in their education, and habits of life and thought. As time softens their prejudices, marriages "across the religion," as our local phrase has it, are becoming more frequent.

I have laid down certain general principles from which we might, reasoning deductively, expect certain results; my observation fully confirms those results. I do not know of a man whose condition has been improved by polygamy, while I could name a score it has reduced to poverty. I cite a few cases within my knowledge, giving no names, but assuring the reader that they are well known to all old residents of Utah:

A has five wives, children by all, and a civil position which gives him $200 per month. In a monogamous community a permanent position of that kind would enable a man of business ability to accumulate wealth. To A with his five wives it is only what $40 per month would be to a monogamist. Despite the great advance in the value of his real estate, he is to-day on the verge of bankruptcy, and unable to properly care for his families.

B is a man of uncommonly fine business abilities, and would anywhere in the States have long since been a millionaire. He has had five wives, and reared twenty children, besides having lost some by death. Five times in his life (so he tells me) he has had a good start; now he is practically without means, the rent of his real estate being consumed in the payment of debts incurred in caring for his family. For years at a time he was never without one or more children sick, and has been literally compelled to repudiate one of his wives, who is supported by her son. Two others have died, and by the most heroic exertions he is barely able to provide for the other two and their seven children, who are still too young to assist.

C holds a very high position in the Mormon Church, and two civil offices, all with good salaries and fine opportunities. In the early days, when the Church ruled everything, the Mormon Legislature made large grants to him of pasture-lands, timber-lands, and water-privileges, to all of which he enjoyed the exclusive right for twenty years. He has had six or seven wives, and children in proportion. Of several fine pieces of property he owns most are mortgaged to their full value, and he is often cruelly embarrassed for money. With such opportunities he should now have been ready to retire with a fortune.

D is an apostle with five wives and a good family to each. Having always been more a missionary than trader, he is now actually an object of charity. It is openly charged, and not very strenuously denied, that one of his wives died of want; all the others either support themselves or are supported by their children, the old gentleman not being able to support even one family. So runs the list. Even Brigham Young, with all his opportunities, cannot be considered very wealthy. He has repeatedly sworn in his entire property at less than half a million, and in his "answer" to the suit of Ann Eliza he put it at $600,000. I should not call that great wealth, for a man with a hundred and twenty children, grandchildren, and sons-in-law, hanging on his financial skirts. The assessed wealth of Utah does not exceed $28,000,000, of which it is known that the Gentile minority owns about one-half. This would leave the 90,000 Mormons no more than $140 each, a lower average, I believe, than in any other part of the United States. The question might well be raised in Congress, whether polygamy did not bring its own punishment to the men; and, if their case alone was to be considered, we might appropriately let it alone. An old lawyer who attends to much of their business gives me his opinion that in ten years nearly all the leading Mormons will be bankrupt.

Another peculiar effect of polygamy I advance, with the suggestion that it may be due somewhat to other causes. As families increase so rapidly in size, amounting in some instances within my knowledge to fifty children of one man, there must be a vast increase in the number of deaths; the father then must suffer an amount of domestic affliction terrible to contemplate, or undergo a progressive hardening of sensibility more to be deplored, even down to a point where the death of an offspring ceases to afflict. To use an awkward commercial phrase, can a man with fifty children, reasonably certain to follow fifteen or twenty to the grave, afford to mourn the death of each one? More than one bishop has a considerable graveyard filled with his own dead. One is said to have seventeen children buried in one row—the longest grave not over four feet. One within my knowledge has thirty-two children living and nineteen dead. Whatever might be the result under happier circumstances, I can only say this of the Mormons: No people in my ken regard death so little, especially the death of young children. They claim that this indifference is a product of their faith, "Death is but a step to a higher sphere;" but I apprehend a lively religious faith, even to the point of belief that an infant is in paradise, does not have that effect. I can understand that something of the same result might follow an excessively large family anywhere; and on this point, too, my observation in Utah convinces me that there is a certain normal size for a family, best attained and very rarely exceeded in monogamy, and that an increase beyond it is productive of misery rather than domestic happiness.

A very curious and subtile effect of polygamy is a tendency toward extreme reticence, habitual concealment of the feelings. It is often said by the Mormon preachers, and daily observation confirms it, that no people in the world keep their feelings and thoughts to themselves so well as the Mormons. Your host may be torn by internal torments, but you will sit at his table many a day ere you discover it. This might be well enough, perhaps, but with it is closely connected an habitual deceit, which, of certain kinds, is all but universal in Utah. Its genesis is partly to be sought in polygamy. A man with more than one wife necessarily lives a lie, pretending an equal affection which he cannot possibly feel; and a policy of concealment is absolutely necessary to maintain peace. Going daily or weekly from one wife to another, he must preserve a determined reticence as to all that passed with the first, or resort to deceit. The wife, too, has her reasons for concealment or prevarication; it never would do to reveal her actual feelings if she means to retain her share of his affections. Whether this, continued through all the months of ante-natal growth, has a marked effect on the offspring, is a question for another branch of science; but certainly that or something else has affected the children of Utah. Deceit is a habit which easily extends from one thing to many, and the effects of this continual falsehood in polygamy are only evil and that continually. The polygamous nations are universally more deceitful in their social relations than the monogamous.

With this is to be connected another method in which polygamy prevents the accumulation of wealth. It tends to the dissipation of social energy. The father to more than one family cannot possibly be a father to either. No man can duplicate himself; and he who begins by having three families and three homes, ends by having none. To this must be added the constant fear, of late years in Utah, of interference by the Government; and thus has been added a new and fearful element of uncertainty to the affairs of life. One result has been to engender suspicion, and a general lack of the monogamic feeling of fixedness; and these in turn prevent large organizations for business. Whatever be the true theory, as things are now, it must be admitted that the family is the cement of the civil structure—the unit, so to speak, from which are successively built up the school-district, township, county, State, and nation—and that without the unit of organization the higher forms could not be evolved. Whatever, then, introduces an element of uncertainty into the family, weakens social cohesion and lessens the ability for organization. Accordingly, we see that no polygamous people ever established a republic or even a remote approach to one; and that in Utah every kind of organization, for business or politics, is headed and managed by the priesthood. Without them it could not have been organized at all. Social cohesion is the one indispensable element in a republic: that a people may practise self-government it is necessary that an overwhelming majority should be able to trust each other, transact business, and regulate their conduct without any government at all. Their social cohesion is certainly weaker among a polygamous people, and must in some way be supplemented; accordingly, theocracy is their natural form of government, and with it springs up a paternalism which aims to take care of the affairs of everybody.

The result of these forces working together gives us the clew to the whole history of Utah. For twenty years the priesthood was absolute spiritually and temporally; the hurch directed everything and governed everybody; every detail of private life was regulated by "counsel;" every public act of the citizen was the subject of some law. Inside the Church proper were three organized governments: the ecclesiastical, the civil, and the financial and industrial. The civil government of the Territory, under the organic act of Utah, passed by Congress, September 9, 1850, was scarcely known except as a convenience by which the Church carried out decrees previously agreed upon in the School of the Prophets. The incumbents of the various offices made elective by the congressional act were first appointed by the Church; the Mormon people then cast a unanimous vote for them under the supervision of the priesthood, every voter's ballot being put on record. Only two instances are known to have occurred of an attempt at political reform. In one of the southern districts some young Mormons nominated a candidate not on the Church ticket and elected him to the Legislature. Reaching the city he was promptly cited before the High Council, as promptly resigned, and the Church nominee was declared elected. A few dissenters in the Thirteenth Ward of Salt Lake City combined with non-Mormons and elected Bishop Woolley to the City Council. He was cited before the School of the Prophets, and subjected to savage abuse by Brigham Young, humbly apologized for his presumption, and resigned; and the regular nominee took the seat. It was the last attempt of that nature inside the Church. That patriotic class of religionists who want an amendment declaring ours a "Christian Protestant Government" would have been delighted with the state of Utah; it was a "religious government" in the broadest sense of the words. The modified theocracy set up in New England by the Puritans was red-republican communism in comparison.

Here and there an individual grew restive under this *régime*, but took good care to say nothing openly; for of all reformers those who strive to rescue men from a mental slavery receive the bitterest opposition from those they seek to aid. If such found the condition intolerable, they quietly slipped out of the Territory and sought a community where public opinion was not so oppressively unanimous. If, as sometimes happened, one failed in the attempt, there was a "man missing—supposed to have been killed by the Indians"—as duly reported in the Church paper. As to the fate of these missing men we are mostly without legal proof, but find a number of candid statements in various sermons preached by the heads of the Church. As instance the following from Brigham Young:

> "Now, you apostates, keep your tongues still, lest sudden destruction come upon you. I say, rather than apostates shall flourish here, I will unsheath my bowie-knife and conquer or die! Now, you nasty apostates, clear out, or judgment will be laid to the line and righteousness to the plummet. If you say it is all right, raise your hands." (All hands up.) "Let us call upon the Lord to assist us in this and every other good work."

Of course, if we should see this quotation in a hostile report, we should reject it at once as a fabrication; but it is in the "Journal of Discourses," with a score of similar passages, the whole book being published by the Mormon Church and indorsed on the title-page by Brigham Young and his councilors. The curious reader may find the doctrine of killing apostates explained and commended in that work, viz.: vol. i., pp. 72, 73, 82, 83; vol. ii., pp. 165, 166, *et seq.;* vol. iii., pp. 226, 234, 235, 237, 241, 246, 247, 279, and in many other passages.

The results of this peculiar system of securing unanimity were curious indeed—well worth the study of the sociologist. The society became perfectly homogeneous. All traces of mental independence vanished. The people even ceased to care for it apparently. A rigid paternalism governed every detail of the social organism under the guise of what was called "counsel by the priesthood." There was counsel to sell and counsel to buy, to go abroad or remain at home, to build a house, open a farm, buy a cow, or take another wife. The remnants of individualism which the people had brought with them from their native lands seem to have completely died out as early as 1855. Natural selection of course operated powerfully in aid of this tendency, coupled with the isolated condition of the country. From one to three thousand fresh converts arrived every year; those who could not submit at once and completely, slipped out of the Territory as soon as possible, and the residuary mass settled into a condition of unchanging homogeneity. That class of thinkers who maintain that government should take care of the people's business, finances, and morals, by prohibitory enactments as to foreign goods and native whiskey, would have been amazed to see how thoroughly Utah had carried out this policy. All the business of the people was regulated by the rulers; paper-money was issued by the city under the direction of the Church; nobody could sell liquor without the consent of Brigham, and the distance from markets created a protective tariff 200 per cent. heavier than a Congress of Greeleys and Careys would have dared to impose. Stranger still, the system was, as to the objects aimed at, a perfect success: a whole community voluntarily abdicated each man his personal sovereignty, and were taken care of by their priestly advisers with a cruel kindness which the ordinary American need not hope to comprehend. Even the desire for independence died out. An original thought came to be regarded as a sin to be repented of, confessed, and put away. Each successive and abortive attempt at something better resulted in making the population still more submissive. Where vigorous preaching had been necessary in 1850, a move of the hand was sufficient in 1860; where argument was still employed in 1860, a hint was enough in 1868. Toward the close of this period, and before the disturbing Gentile invasion, business took me on a lengthy tour through the remote settlements, where the results of over-government showed themselves most completely in the perversion or stupefaction of the mental faculties. I heard men maintain with vehemence that Jesus Christ was a practical polygamist; that the Gentile world was to be utterly desolated before 1890, and the remnant submit to the Mormon priesthood; that a republican government was a rebellion against God, in that men sought to govern themselves without counsel of an inspired priesthood and a prophet divinely appointed; and that a man could not obtain honorable rank in heaven unless he had children on earth. I heard women protest that they would not live as the one wife of a man if possible to go into polygamy; that there was no exaltation in heaven to an unmarried woman; that it was a deadly sin to refuse to enter polygamy; and that a woman or man who voluntarily remained unmarried would be a servant to the Saints to all eternity. Both sexes accepted as a religious verity that slavery and polygamy were established by direct command of God; that the Government was at war with the Almighty in the abolition of one and disapproval of the other; and that the mass of the people of the United States were scoundrels who deserved death, and would soon be visited with all the plagues of the Apocalypse. And these people did not seem to be aware that they were insane. They argued earnestly and swore fluently in defense of their religion, quoted the Bible voluminously in favor of slavery and concubinage, and declaimed about the Prince of Peace, the way of salvation, and control of passion, till they were black in the face with anger. At the autumn conference that year Brigham pronounced the fiat—"No trade with outsiders;" and at a wave of his hand all the commercial relations of 75,000 people were changed in a day; a dozen mercantile firms had their business destroyed, and were driven from the country. Some of them could not even dispose of their stock on hand, and were forced into bankruptcy. That autumn I visited one settlement, near Salt Lake City, where a cane-mill was run night and day on custom-work. A year afterward I passed that way again; the cane-mill was resting in idleness, and the people hauling their cane miles away to another settlement. The owner of the mill had apostatized; the word from the Tabernacle had gone forth, "Drop him!" and for the first, and I hope the last, time in my life I got sight of that unique theological phenomenon—an apostate cane-mill.

Whether the moral condition was then tolerably good or very bad cannot be determined satisfactorily. There was such a dead calm upon the surface of society, and such a singular reticence among all classes, that only the most atrocious cases ever came to light—often those were not known or suspected until some of the parties had apostatized. No account was ever given in the Mormon papers of any crimes committed in the remote settlements, and so complete was the surveillance of the secret police that a case of seduction was almost immediately discovered and settled by having the parties married at once, a previous marriage of the man being no hinderance. Of two strangers visiting the Territory, one would say: "These are the most orderly, law-abiding, and happy people on earth;" the other: "There is neither liberty nor law—neither honest, earnest thought nor vigorous happiness; there is a centralized despotism, and Brigham Young is king." Possibly some idea of the moral tone may be gained by noting the prominent characters chosen for the offices, and presumably representing the priesthood and people. John D. Lee, as well known then as now as the wholesale murderer of Mountain Meadows, only a few months after that awful crime came to represent Iron County in the Legislature, received the encomiums due a faithful public servant, and went home with a young wife, "sealed" to him by Brigham Young. His colleague in murder, Isaac C. Haight, was also his colleague in the Legislature, and was in like manner rewarded with a young wife. Both these men continued high in office in the

Mormon Church until the United States marshals chased them into the mountains. Robert T. Burton, who murdered four of the "Morrisites" after their surrender, was rewarded with the offices of collector, sheriff, and bishop, and two extra wives given him. Bill Hickman, who confesses to twenty murders, was a member of the Legislature, and had during his career ten wives. Samuel Smith, Bishop of Boxelder, rejoices, presumably, in the ownership of six wives, of whom two are his brother's daughters. It is not conclusive that these men represented the average moral tone, as they were appointed by Brigham before being elected by the voters; nevertheless, I do not remember having heard the appointment spoken of with disapprobation by the people. I visited both Haight and Lee at their homes in Southern Utah, and, while the latter was under some popular condemnation, the former was a leading citizen of Toquerville. Polygamy, like slavery, is necessarily the practice of a minority—a select aristocracy; but in both cases it is to be noted that the great majority who could not enjoy its benefits, if any, were its most ardent defenders. Could this social and political condition have continued three generations, then would the future scientist have found in Utah an entirely new variety of our species—Saxons without a constitutional government, Britons with no consciousness of a personal sovereignty, Americans lacking even the wish for a republic; wives willing to share a husband's heart, maidens looking for an "exaltation" in polygamy, and children with blood relationship so mixed that no "heraldry Harvey" could ever have succeeded in tracing the circulation. From a scientific standpoint, it is almost a pity the Gentile could not have left Utah untouched for a century—it would have been such an interesting experiment. With the Gentile invasion and establishment of United States authority, the experiment practically comes to an end; but, let it be dealt with as wisely and mercifully as it may, the break-up must be attended with fearful suffering.

## SKETCH OF PROF. J. S. NEWBERRY, M. D., LL. D.

JOHN STRONG NEWBERRY, whose portrait we give in the present number of the MONTHLY, was born December 22, 1822, at Windsor, Connecticut. He is sprung from old Puritan stock, his ancestors having formed part of a colony which, in 1635, emigrated from Dorchester in the colony of Massachusetts Bay, and made the first settlement in Connecticut, at Windsor. Many members of the Newberry family earned high distinction by their services in the field and in the council during the colonial period, in the War of Independence, and in the later history of Connecticut.

The grandfather of J. S. Newberry, General Roger Newberry, an officer in the army during the Revolutionary War, was for many years a member of the Governor's Council; he was also one of the directors of the Connecticut Land Company, proprietors of a great part of the "Western Reserve," in Northern Ohio. His son Henry, father of the subject of this notice, in 1824, with his family, emigrated from Windsor to the Western Reserve, and founded the town of Cuyahoga Falls, in Summit County.

Young Newberry received his academic education at the Western Reserve College, from which institution he graduated in 1846. Two years later he received the degree of Doctor of Medicine from the Cleveland Medical College. The years 1849–'50 he spent in study and in foreign travel, and in 1851 he began the practice of medicine at Cleveland. But the life of a practising physician was distasteful to Dr. Newberry, as affording but little opportunity for scientific study, for which he had from boyhood evinced great aptitude. Hence, in May, 1855, he accepted an appointment as assistant surgeon and geologist to Lieutenant Williamson's expedition for the exploration of the country lying between San Francisco and the Columbia River. The results of this expedition are published in the Pacific Railroad "Reports;" but Dr. Newberry's report on "The Geology, Botany, and Zoölogy of Northern California and Oregon" also appears in a separate quarto volume of 300 pages, with 48 plates.

He next, in 1857–'58, was attached to an expedition under the command of Lieutenant J. C. Ives, commissioned to explore and navigate the Colorado River, so as to open a route of communication with the army in Utah. An iron steamer, constructed in Philadelphia, was taken in sections to the Gulf of California, where it was put together and launched. The expedition navigated the river for the distance of 500 miles. Above the point reached by the steamer the course of the river, for hundreds of miles, is through deep cañons with vertical walls, in some places over a mile in height. The report on the Colorado region, drawn up conjointly by Lieutenant Ives and Dr. Newberry, gives a graphic description of perhaps the most remarkable portion of the earth's surface. In the preface to the report, Lieutenant Ives speaks of Newberry's observations as constituting "the most interesting material gathered by the expedition."

The following year (1859) Dr. Newberry was ordered to join a party sent out by the War Department, to report to Captain Macomb, for the exploration of the San Juan and Upper Colorado Rivers. The party traversed a large part of Southern Colorado, Utah, Northern Arizona, and New Mexico, adding greatly to the sum of geographical knowledge, and opening a region of singular interest and of enormous mineral wealth. This expedition determined the point of junction of the Grand and Green Rivers, forming the Colorado; further, it explored the valley of the San Juan, a river whose banks for hundreds of miles are lined with the ruined stone houses and towns of an extinct race. Dr. Newberry's report of this expedition was published recently.

Upon the outbreak of the war, Dr. Newberry was elected a member of the Sanitary Commission, and in September, 1861, he was chosen secretary of its Western department. He had supervision of the affairs of the Commission in the Mississippi Valley, with headquarters at first in Cleveland, then in Louisville. In this position he displayed executive abilities of a high order. Branches of the Commission were, through his efforts, established in the chief cities of the West, and measures taken for the permanent and effective care of the sick and wounded.

In 1866 he was appointed Professor of Geology in the School of Mines of Columbia College, New York, which position he still holds. In 1869 he received from Governor Hayes the appointment as State Geologist of Ohio, and was commissioned to make a geological survey of that State. The work was carried on by Dr. Newberry and his assistants with extraordinary vigor, and was completed at the close of the year 1874.

The report of this survey is now in process of publication. Two "Reports of Progress," and four volumes of the "Final Report," illustrated with a large number of finely-executed maps and plates, have already appeared. Four volumes more, and a geological map of the State, still remain to be published. This work, though executed with unexampled rapidity, has not been carelessly done. The record already made is proof of its thoroughness, and shows that it will compare favorably with any similar survey made in this country or elsewhere; indeed, it is in the highest degree creditable to the State of Ohio, and to the geologist in charge.

Prof. Newberry's eminence as a scientific man is unquestioned. As a geologist and paleontologist he ranks among the foremost of the time. His contributions to the literature of these branches of science have been numerous and valuable, being chiefly in the departments of general geology, fossil plants, and fossil fishes. He is a member of most of our American scientific associations, and of many similar European bodies; he was one of the original corporators of the National Academy of Sciences, has been President of the American Association for the Advancement of Science, and is at the present time President of the New York Academy of Sciences (formerly Lyceum of Natural History).

# CORRESPONDENCE.

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## EARLY TRANSCONTINENTAL EXPLORATIONS.

*To the Editor of the Popular Science Monthly.*

SIR: Judge Daly's address to the American Geographical Society, in the May number of THE POPULAR SCIENCE MONTHLY, it appears to me, might lead the reader to infer that little was known, before General Fremont's journey, of our country between the Mississippi and Pacific. And a like opinion seems to have been entertained when he was a candidate for President, for it was then said that he was the discoverer of the South Pass of the Rocky Mountains; whereas it had been long known and used by explorers before 1832, ten years before his journey, when I passed that way to Oregon, some account of which can be seen in a letter from me to Prof. Amos Eaton, of Troy, published in *Silliman's Journal* in 1833 or 1834, and a communication from myself to the same in 1835. But, as this may look a little egotistical, I will speak of those who traversed those regions earlier, but by no means to detract from the deserved honor due to those later explorers named by the judge in his address, one of whom, Lieutenant Gunnison, I knew well, as this place was for a time his home, as it is still of his family; and as they were the first to explore the wide country from the Mississippi to the Pacific, Lewis and Clark, and their companions, should be the first mentioned, for, till their exploration, it was indeed a *terra incognita*. Sent out by the Government in 1806, after its purchase as a part of Louisiana, it took them more than two years to perform the journey, crossing the mountains by very difficult routes, the more feasible ones, the South Pass and others, being of after-discovery. Well do I recollect in my childhood hearing one of their number, a Mr. Ordway, describe their journey, and how the *bad* Indians followed them for a number of days to restore some articles they had accidentally left. Lewis and Clark's journey was before the day of what is called the modern sciences, for to them, geologically, the grand basaltic columns on the Columbia were "*high black rocks*." Then, in 1810, came Mr. Astor's grand enterprise of establishing the fur-business on the Columbia. He not only sent a vessel round by sea with men and supplies, but sent a party, headed by Mr. Ramsay Crooks, across the country to meet them. He met so many obstacles, especially among the mountains and cañons along the lower Lewis River, that he did not reach Astoria till the second year. The next year, to bring an express from there to Mr. Astor, a Mr. Robert Stewart, late of Detroit, crossed the mountains and plains with only half a dozen men. But Astor was cut short in his business in Oregon, for in 1812 a party of the British Northwestern Company crossed the mountains and descended the Columbia, carrying the news to Astoria of the war, and that a war-ship was on the way to take their fort. So Astor's agents there sold out to them his interest, and those British traders, afterward consolidated with and known as the Hudson Bay Company, even after the boundary-line was settled beyond the mountains, controlled the fur-trade from the Pacific to the Atlantic in British America, and down the coast to California, and knew every corner of it to the Arctic Ocean, wherever the beaver clipped a twig or swam its mountain-streams. General Ashley, and other American fur-traders, early also carried the trade to the mountains, and became as well acquainted with them on our side, if we except that wondrous cañon-region lately so ably explored by Powell and others. Mr. Sublelle, with whom and his trappers we in 1832 traveled, had then made his seventh annual journey to the mountains, and we left the State of Missouri on the deep-worn Santa Fé trail, over which trade was carried on to that place; leaving which, and crossing the Kansas River, between that and the Platte we overtook Major Bonneville, traveling with wagons to the mountains, where he passed the winter, and of whom, as well as of Astoria, Mr. Irving gives an interesting account. We parted with the trappers on what I now know to be the Humboldt River of Utah, and in six weeks reached the Hudson Bay Company's fort, Walla Walla, through a country so poor in furs that it had been little frequented by their traders. So the Indians showed us their usual native kindness and hospitality. And here let me say, after a long acquaintance with them, that Indians, uncontaminated by the whites, are *honest*, *truthful*, and *hospitable*.

JOHN BALL.

GRAND RAPIDS, MICHIGAN, *May* 5, 1876.

### THE DISCOVERY OF A SPECIES OF BORING MOTH IN FLORIDA.

*To the Editor of The Popular Science Monthly.*

THE notice in the June number of THE POPULAR SCIENCE MONTHLY (p. 250) of the species of *Ophideres*, moths which possess a trunk so rigid as to be able to pierce the rinds of oranges and suck their juice, has brought to light the occurrence of a species of the genus in Florida. The specimen which I have examined was taken by Mr. Roland Thaxter, of Newtonville, Massachusetts, near Appalachicola, Florida, on March 24th of this year. Mr. Thaxter, who is already known for his collections of our Northern *Noctuæ*, preparing them beautifully for the cabinet, has added greatly to our knowledge of this group; the species *Eutolype Rolandi* and *Dicopis Thaxterianus* have been named for him. The present discovery, which he has made during a winter's trip to Florida, is equally interesting. The Florida specimen seems to me undoubtedly to be *Ophideres materna* (Linn.), a species proper to the East Indies, but which Guenée records also from Brazil, conjecturing that it had been transported thither by commerce. I have examined the terebrant trunk under the microscope, and it agrees in the main with the representation of that of *Ophideres fullonica* given in THE POPULAR SCIENCE MONTHLY (p. 251). It is not possible to compare it more nearly without mounting the end of the trunk as a microscopic object, which the rarity of the single specimen prevents. It is not unlikely, now that the species is found, that it will be discovered in larger numbers, while the interesting question as to its introduction into Florida will engage attention. The most probable conjecture will associate it with its food-plant.

A. R. GROTE.

## EDITOR'S TABLE.

### *THE PROMOTION OF SCIENCE.*

THE importance of science is everywhere conceded. As affording a knowledge of the operations of Nature, which can be taken advantage of by multiplying the resources and increasing the productiveness of industry, and by guiding art into the most economical ways, everybody admits that science is doing a beneficent work for the world. And even in the region of ideas, as a basis for the formation of opinions and a corrective of old errors, the importance of science is freely acknowledged. That science is something of universal moment, and of the deepest interest it is almost superfluous to argue; its recognition is so far assured.

But science is also, and as a consequence of its importance, something to be *promoted*. It is something of which myriads of human beings scattered over the globe know nothing; which the world got along without for more ages than we can count; which slowly arose in these latter centuries and grew against steady resistance, and which has at last among certain nations come to be a separate interest cherished by a portion of the cultivated classes, and so distinctly recognized as needing care and encouragement that many organizations have arisen to promote these objects. Royal societies for the "promotion of natural knowledge," academies of science in all the chief cities, special societies devoted to each of the great branches of science, local institutions, naturalists' clubs, and large popular associations for the advancement of science, as in Germany, France, England, and this country, which hold their meetings in the different cities so as to act upon large numbers of people—all these are illustrations of the tendency to organize for the promotion of science by increasing observations, experiments, and original researches for the improvement and extension of this kind of knowledge. Nor are there many obstacles to these modes of work, save those which spring from its inherent difficulties. It is a very expensive kind of study, involving costly instruments, elaborate investigations, and extensive collections—the sending of expeditions into remote and unknown regions, and of ships around the world to scrape the bottom of the sea. The universally confessed importance of such inquiries has already secured large appropriations for these objects, and it may be expected that in future private enterprise and governmental aid will become still more available for these objects.

But there is another agency for the promotion of science, which we hold to be of far greater importance than all these immediate means and instrumentalities, and which the world has hardly yet begun seriously to consider. We refer to the alliance between science and general education. Science has hitherto accomplished its work with but very imperfect assistance from this source. Education in all its grades has been in the interest of other classes, and it does not even yet distinctly, or fairly, recognize as a class the students of Nature. There have been innumerable institutions strongly endowed, and ably equipped for the intellectual training of lawyers, clergymen, physicians, linguists, metaphysicians, historians, and literary men, but the facilities for the systematic training of scientific students have been scanty, defective, or altogether wanting. Education was highly organized before science arose, and the old institutions not only did not encourage the experimental study of Nature, but resisted it, with the whole weight of their influence, for centuries. The universities were creatures of the church and the state, and devoted to ideas, and ideals of culture, which were unfavorable for the study of natural things, and obstructive to scientific investigation. The old educational institutions have been, of course, greatly modified and liberalized, in recent times, yet tradition continues in the ascendant, so that, although science has forced its way into many of them, it is still regarded with jealousy and treated as an intruder. Though within the pale of official recognition, it is dealt with as something outside of the venerated curriculum of liberal study. It has not been assimilated so as to become an integral and necessary part of our modern culture, and college authorities are still perplexed to decide how much to concede to it, and what to do with it. Scientific men have, therefore, grown up under unfavorable conditions, and have not had those advantages of early preparation, of cordial encouragement, and of long and faithful discipline, which the students in other departments have freely enjoyed. It is under these grave disadvantages that science has, thus far, advanced. Education has been made only very partially tributary to its progress. When it takes its rightful place in our schemes of study, when it is honored as other acquirements are honored, and when the higher institutions offer the same facilities for prolonged and thorough scientific discipline that they offer for training in classics and mathematics, a step will have been taken toward the general promotion of science, more important in its consequences than any measures that have been hitherto adopted.

And yet this will be but a partial step in the right direction. The bringing of education into the full service of science means much more than its liberal acceptance by the higher schools. Science is a vast and a permanent interest in human society, and in considering the means of its advancement we are bound to take account of those deeper agencies which require time for the accomplishment of their results. More important for the general promotion of science than any change of policy on the part of the colleges, will be its recognition and adoption as a part of the established work of primary and common schools. The most urgent question now, and fullest of import for the future, is the relation which science is to take to elementary education. Thus far, the course of science has been a continuous battle, and it has only got what it has conquered. Its claims have been pressed by its advocates, and they have been resisted by the partisans of other studies, and we observe that the instincts of the combatants are bringing them rapidly to the vital issues of the strife. As we have often said, the most critical and important question between the old education and the new is, which shall have authority to form the first impressions in childhood. The practical inquiry is, How early shall children be allowed to begin the study of science in schools? We can imagine a future time, and we trust it is not far distant, when such an inquiry will be regarded as absurd. Science being an understanding of natural things, and a child being born into the order of Nature, with a capacity for intelligence which is awakened and unfolded only by its intercourse with natural things, what can be more preposterous than to raise the question when a child shall begin to have its attention thoughtfully directed to the objects around it? In this dawning action of the mind upon sensible things are found the rudiments of all science. Obviously, the true requirement is, that these germinal acquisitions concerning the kinds, and properties, and changes, and relations of things around, shall become matters of early attention, encouragement, and cultivation, on the part of parents and teachers; and, if this were intelligently and skillfully given, the query could never arise, When shall the study of science begin? But we are far enough from that condition now. In accordance with the prevailing ideas of education, the child is got into the schoolroom as early as possible, and, being started in a course of acquisition in which science is left out, the question at length arises, If it is to be introduced at all, when shall it commence? The advocates of the old education would never ask for it. They would occupy childhood, and youth, and manhood, with language, grammar, and book-acquisitions, so that the pupil and the student would get no more knowledge of the laws and phenomena of Nature than they had before this knowledge was discovered. And, when pressed by the advocates of the new education to make room for scientific studies, they defer it as long as they can, and allow it as little time as possible.

A very interesting controversy has gone on for some time past, in the columns of *Nature*, as to how early science is to be entered upon in the preparatory schools. All the writers profess to represent the liberal side, yet some of them who admit the importance of science assign it a low value as a means of education, and think that children should not touch a scientific subject in school until they are well grounded in Latin and geometry. This is substantially a surrender of the whole ground; yet it is the position taken in the great mass of schools in which the sciences are regarded as only fit for finishing studies. The physicists and chemists are more in earnest, and believe in the educational usefulness and importance of their subjects, but they seem more concerned about the consideration given to their chosen sciences than about the mental needs of children, and the adaptation of objective studies to their early cultivation. They would therefore begin with physics and chemistry when boys and girls are old enough to commence simple experimenting; that is, at perhaps the age of twelve or thirteen. Mr. Wyles, of Allesley Park College, claims to have had the best success with chemical and physical experiments and the use of the microscope, and he embodies his views and results in the following instructive passage:

"I believe that such knowledge as I have indicated may be profitably given even to very young boys. They learn thereby to distinguish the precise features and qualities of natural objects, and the conditions of ordinary phenomena; and such teaching undoubtedly exercises in the best way the observing powers, which develop much earlier than the reflective faculty. I am inclined to say that teaching elementary science to boys from ten to thirteen is a greater success than teaching grammar; i. e., that the principles involved are more easily seen, excite more interest, and become therefore a better mental discipline. We rarely have boys come to us with any knowledge of science, and, when they have, it has generally been acquired from lectures, and is worthless as a means of education. We do not lecture, but do real hard class-work, and take periodical examinations on this work, giving it equal value in these and our grade examinations with language and mathematics. We have no reason to believe that this work interferes with or deteriorates the work in language and mathematics, in which subjects we find our boys quite equal, and, except in very rare cases, I may say, superior to incomers of like power, and who have had no science-teaching.

"The great number of men eminent for their vast scientific attainments, who have achieved this eminence in spite of our non-scientific, I may almost say anti-scientific system of education, clearly indicates that many of us have an inherent scientific power or genius surpassing our power in any other direction. I plead for such that they have the same chance of being floated on their scientific voyage as the linguist and the mathematician have on theirs: and I have seen no satisfactory plea why they should not. Value for value, I claim for the science-man a higher status in our present social life than is due to either linguist or mathematician.

"My experience as a schoolmaster has revealed to me many cases where the talent for language or mathematics has been so low that the education effected by these has been of the meanest kind; or where the incessant failure has produced a stolid ignorance, a kind of mental paralysis, most disheartening to all concerned. Such cases have come into my hands, and I have seen intelligence rekindled, and mental power aroused, by simple science-teaching, and the power even for other subjects enhanced thereby."

But there are others who insist that scientific studies may and should begin much earlier, and their view must be adopted before society can ever reach the solid and lasting advantages which are to be gained by scientific education. It is the teachers of natural history that favor this view, maintaining that the collection, observation, and comparison of plants, insects, shells, etc., may be made highly instructive at a period when chemical and physical experiments may not be undertaken. The Rev. George Henslow takes this decided position, and, in replying to Mr. Wilson, of Rugby, in *Nature*, of April 20th, he has the following remarks:

"Before twelve, I agree with Mr. Wilson, that practical chemistry should not begin. But, Mr. Wilson says, 'Science should be introduced into a school, beginning at the top and going downward gradually to a point which will be indicated by experience.' Surely this is inverting a fundamental principle of education, and we may ask, Why should science be thus singled out? Why not begin at the top with Latin and arithmetic and work downward? Science, however, has its 'elements' and its 'advanced' stages, like everything else. The soundest method seems to me to select the science for each age or capacity of pupils, and for the teacher himself to adapt the branch selected to them. Let him begin with botany—with children of the age of six, if he pleases—and by using the schedule he will find it almost self-adapting to the child's powers. Physical geography might come next, with pupils from eight to twelve; then the experimental sciences or geology from twelve upward. The observing of the habits of animals might go along with any other science as an out-door instructive amusement, and be limited to no age.

"Mr. Wilson talks of the difficulty of a 'bored and weary schoolmaster teaching science informally.' Passing by the fact that, if he be bored and weary, it is largely due to his own want of interest in teaching, or in engaging that of his pupils, I would maintain just the opposite opinion—that, assuming a teacher to be such, informal teaching in natural history has a wonderfully invigorating effect, and reawakens the attention which may have become dull by monotony. Thus I have often found, during a lesson in Latin, e. g., Virgil's 'Georgics,' passages to be constantly occurring when 'collateral science' can be invoked. And, what is a proof of its value is, that it becomes suggestive to the pupils themselves, so that I have been obliged to check the superabundance of questions lest a Latin lesson should resolve itself into one on natural history.

"Beyond such informal teaching as this I would never encourage it as a principle for teachers solely to act upon with young children, though, of course, there need be no restrictions in giving it them. But if science is to be *taught* at all—and all such informal methods are not really teaching—let it be thorough as far as it goes, lest it should lapse into a slipshod informality. It is the charm of the schedule-system of botany that it demands close and accurate observation in the dissections, and the writing compels accuracy in the result, as well as impresses the facts firmly upon the memory."

## *CRIMINAL JUSTICE IN* 1876.

One of the objects of this Government, avowed by its founders in the preamble to the Constitution, is *to establish justice.* The implication here is that there are such things as human rights which require to be protected, and that it is the office of government to enforce this protection. The first utterance to the world of the American people, in detaching themselves from the parent-country and proclaiming independence, was an affirmation of "inalienable rights," to secure which "governments are instituted among men." We may infer from this that it is the first, the supreme, and the acknowledged duty of the governing power in society to guarantee the rights of citizens, and to see to the strict enforcement of justice. The presumption is that, in the free interactions of citizens in the social state, wrongs will occur, rights will be violated, and injustice be done. The innocent will be circumvented by the crafty, the weak will be oppressed by the strong, the unscrupulous will combine to plunder the helpless, and, to prevent all this, Legislatures enact laws, courts are established, judges, sheriffs, and constables appointed to carry them out and secure the requirements of justice. This is the boasted theory of our civil institutions, but, after a hundred years of experience and improvement and progress, it is painful to note the enormous gap that still exists between theory and practice. That government should fail to secure its great ends in a perfect manner is what might be expected from the imperfection of all human institutions. Though devoted assiduously to this great object, such are its difficulties, and such the ingenuity of the practised perpetrators of wrong, that we should be entitled to expect from government only a very partial accomplishment of its purpose. Another and a very powerful cause of the inefficient execution of justice in society is, that government perpetually forgets its supreme function, in the pursuit of other ends. It attempts to do so many things that it does nothing well, and sacrifices the very object for which it was instituted, in the attempt to accomplish others which it had no business to undertake. Instead of confining itself vigorously to establishing justice in all the relations of society, and then allowing the widest liberty of individual action and enterprise, it meddles with everything and everybody, interfering, checking, and restraining, where it should let things alone, and undertaking to play the part of Providence in controlling the whole course of human interests. Justice is thus not only neglected, but injustice is wrought in all directions, so that government at last becomes the instrument and partner of the great agencies of oppression and wrong-doing in society. Nor is this the worst: instead of concentrating its attention upon the transcendent duty of working out the great ends of justice, and laboring to improve and perfect the methods and appliances for attaining this object, it stands convicted as the open and shameless perpetrator of wrong, violator of the most sacred rights of citizens and the defiant executor of palpable and rank injustice. The prosecutor of criminals, it becomes itself the criminal, and cuts off its victim from all possibility of redress.

An illustration of this has just occurred, which is worth pondering over in this year consecrated to political vainglory. The newspapers inform us that "in November, 1874, Charles and Mary Fisher were sentenced in the county of New York, the former to seven and the latter to five years' imprisonment in Sing Sing, for being accessory to an outrage upon a girl. The governor has pardoned both, upon the representation of the prosecuting officer that they were innocent of the crime." Government has here perpetrated a gross injustice upon two innocent persons—deprived them of their liberty, extorted labor from them, and robbed them of the results of it, subjected them to a cruel degradation, and, when convicted of its own blundering, it lets its victims go without lifting a finger toward repairing the wrongs it has inflicted; Charles and Mary Fisher are without redress. If their rights had been similarly violated by other individuals, government would have recognized their claims to large compensation. But when its own court and its own officers are the self-convicted offenders, those who have suffered may ask reparation in vain. If a citizen is wrongfully deprived of his property by government, he may prosecute and recover it to the uttermost farthing; but, if wrongfully imprisoned, stripped of his wages and disgraced by the very authority that was constituted to mete out equal justice to all, its victims are helpless. If an American citizen were unjustly imprisoned abroad, the government would have redress from the offending nation, though at the cost of war. But when the same thing occurs under its own jurisdiction and by its own fault, all reparation is denied. It may be said that such things cannot occur often; then they are the more easily rectified, and the excuse for withholding justice is only an aggravation. But it is probable that they occur far more often than the public is aware of. For what have we to hope, in the strict administration of justice, from an authority that can itself outrage justice in so glaring a way? What are we to expect from an authority that refuses to hold itself accountable for the wrongs it does. If it be said that the government must assume the infallibility of its ministration of justice, then why liberate Charles and Mary Fisher? And, if the machinery of justice can work so ill as utterly to defeat itself, the proof of which we have in this flagrant case, what confidence have we in the proportions and measures of penalties that are meted out to real criminals? With such obtuseness and indifference to right and wrong as are evinced in this scandalous case, there is surely little confidence to be reposed in the general equities of criminal adjudication. There can be little doubt that the coarsest and most barbarous part of our administration of law relates to the treatment of the criminal classes.

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### *PROF. HUXLEY'S LECTURES.*

Prof. Huxley has decided that, from the nature of his engagements, he must give up all expectation of visiting the United States during the winter, and that therefore it would be impossible for him to devote a season to lecturing here. But he is coming over in August to spend a brief vacation of a few weeks in this country, and, although strongly desirous of forgetting all lecturing, and being left quietly to himself while here, he has, nevertheless, consented to give three lectures during the last week of his stay. He will speak in New York on the 18th, 20th, and 22d of September, the subject being "The Direct Evidence of Evolution." This will give an opportunity, for those persons throughout the country who are anxious to hear Prof. Huxley, to connect this pleasure with their September visit to the Centennial Exhibition. It is to be remembered that these are the only lectures that Prof. Huxley will give in this country, and they will probably be fortunate who obtain the tickets. Detailed arrangements are not yet made, but parties wishing to secure seats can do so by applying to the editor of The Popular Science Monthly, who will register applications in the order in which they are received, the first applicants for tickets having the first choice of places.

## LITERARY NOTICES.

Prehistoric Man: Researches into the Origin of Civilization in the Old and the New World. By Daniel Wilson, LL. D., F. R. S. E. Third edition, revised and enlarged, with Illustrations. In Two Volumes. London: Macmillan & Co., 1876. Price, $12.

The first edition of this important work was issued in 1862, at a period when the public mind was startled by the rapid progress made in archæological discovery, and by the evidence it afforded of the great antiquity of man upon the globe. Vast collections of implements and ornaments had been made by the museums of Northern Europe, and by private collectors, from caves, mounds, lake-borders, and drift-gravels, but their value as a record of the prehistoric races was a subject of animated discussion. It was not admitted, excepting by those familiar with the subject, that any of the implements which had been brought to light "implied a longer period for man than that assigned by the Mosaic record."

It was vigorously denied that flint weapons found in the ancient drift-gravels were works of art. M. Boucher de Perthes published, in 1847, an account of many found in the drift-gravels in Northern France, and for many years "was looked upon as an enthusiast, almost as a madman." At such a period the appearance of Dr. Wilson's elaborate work, and of others like it, did excellent service, in presenting the facts and history of archæological science, and the conclusions it suggests.

In common with those who had made the science a subject of unprejudiced study, he asserted the great antiquity of man. "The pre-Celtic architects of the British long barrows, and the allophyliæ of the European stone age," he said, "are but men of yesterday, in comparison with the Flint Folk of the Drift. . . . They were a race of hunters and fishers . . . . contemporary with the Siberian mammoth and extinct elephants—the woolly rhinoceros—the musk-ox, and reindeer of France."

The present volumes contain an account of the principal discoveries made since the first edition appeared, and treat in interesting detail of the condition of primitive man on this continent—the aspects of culture among the mound-builders, and the miners of the Northern lakes. The civilizations of Mexico and Peru, and the shadowy ones which preceded them, are vividly presented.

Here, as everywhere else with primitive man, the author finds proof that "art is a child of necessity." Probably men learned to sharpen stones for their clubs, converting them into spears when the club was found inadequate to the necessities of their condition.

Man's earliest arts were therefore of the most practical kind, not in any sense ornamental. Indeed, ornamentation arose, in the opinion of the author, merely by improving the accidents of manufacture.

The era of the Flint Folk, he observes, may antedate the historic epoch by hundreds of thousands of years, as some archæologists insist; "still man is found to have been the same reasoning, tentative, and inventive mechanician that he now is." Nor does the author find any evidence of the anthropoid link between man and the brute. It is obvious, however, that much depends on what constitutes evidence of that link, and scientists differ on that point.

Only that portion of the early prehistoric period is known to us of which the caves and the drift have furnished records; these, however, suggest an antecedent period, in which man may not have attained the weapon-making stage. His primeval habitat and true birthplace, observes the author, may have been in the more favored regions of the earth where Nature spontaneously provided for his requirements.

That a work so voluminous as this should pass to a third edition is strong evidence of its merit, and of the deep interest felt in the subject of which it treats. The value of the work is enhanced by the number of its illustrations, there being 132 in the 800 pages of the volumes. It is the matured and intelligent expression of one of the early students of archæology, and will continue to command the attention of the specialist and of the general reader.

### The Wages Question: A Treatise on Wages and the Wages-Class. By Francis A. Walker, M. A., Ph. D. New York: Henry Holt & Co. Pp. 428. Price, $3.50.

The question of wages is strictly economical in its nature, and must be discussed by the political economist without reference to ethical or social considerations. Most writers on the subject of wages have, however, given to the term "economical" too restricted a meaning, thus excluding the action of causes which, though primarily ethical or social, are nevertheless secondarily potent in the field of industry, as affecting either the production or the distribution of wealth. To such causes Prof. Walker assigns due weight, and herein consists one of the distinctive features of his work. "Sympathy for labor" is a phrase which, on first view, would seem to have no place in a scientific discussion of the wages question from the political economist's point of view. Yet, as is shown by the author, if sympathy for labor serves in any degree to make competition on the side of the laboring class more active and persistent; if it takes anything from the activity and persistency with which the employing class use the means in their power to beat down wages, or lengthen the hours of work, it becomes, in just so far as it has such an effect, a strictly economical cause.

Three doctrines, which are more or less current in political economy, the author vehemently controverts, viz.: 1. That there is a wage-fund irrespective of the numbers and industrial quality of the laboring population, constituting the sole source from which wages can at any time by drawn. Wages, he shows, are paid out of current production, and not out of capital, as the wage-fund theory assumes. 2. That competition is so far perfect that the laborer, as producer, always realizes the highest wages which the employer can afford to pay; or else, as consumer, is recompensed in the lower price of commodities for any injury he may chance to suffer as producer. 3. That, in the organization of modern industrial society, the laborer and the capitalist are together sufficient unto production, the actual employer of labor being regarded as the capitalist, or else as the mere stipendiary agent and creature of the capitalist, receiving a remuneration which can properly be treated like the wages of ordinary labor.

In opposition to the generally-accepted view that, if the wage-laborer does not seek his interest, his interest will seek him, Prof. Walker holds that, *if the wage-laborer does not pursue his interest, he loses his interest.* "In a state of imperfect competition," says the author—

> "First, wages may be reduced without any enhancement of profits, the difference being, not gain to the employer, but loss to mankind through the industrial degradation of the laborer." This point is established by the case of Spitalfields, where a large population was ruined morally and socially by a great change in the conditions of the silk manufacture. "Secondly," continues our author, "for so much of the sums taken from the laboring class by reduction of wages as the employers or capitalists may at the time secure in excessive profits or excessive interest, there exists no adequate security, under the operation of strictly economical forces, that it will be fully returned to the wages-class in a quickened demand for their labor, inasmuch as luxuriousness and indolence will inevitably enter, among the majority of employers, to waste in self-indulgence a portion of the profits so acquired, or to take something from the activity and the carefulness with which future production will be pursued. Thirdly, in respect to such industrial injuries as have just been described, economical forces by themselves tend to perpetuate and continually to deepen the injury, putting the laborer at a constantly-increasing disadvantage in the exchange of his services."

The doctrine of *laissez faire* is simply a rule of conduct applicable in certain conditions, not a principle of universal application. Prof. Walker favors state interference to the extent of—1, insisting on the thorough primary education of the whole population; 2, advocating a strict system of sanitary administration; 3, insisting on the necessity of precautions for the integrity of banks of savings for the encouragement of the instincts of frugality, sobriety, and industry. "If the state," says he, "will see to it that the whole body of the people can read and write and cipher; that the common air and common water—which no individual vigilance can protect, yet on which depend, in a degree which few even of intelligent persons comprehend, the public health and the laboring power of a populations—are kept pure; and that the first feeble efforts of the poor at bettering their condition are guarded against official frauds and speculative risks, it may take its hands off at a hundred other points, and trust its citizens, in the main, to do and care for themselves. . . . It must ever be borne in mind, in such discussions, that those things are economically justified which can reasonably be shown to contribute, on the whole, and in the long-run, to a larger production, or, production remaining the same, to a more equitable distribution of wealth."

### Annual Record of Science and Industry for 1875. By Spencer F. Baird. Pp. 946. New York: Harper & Brothers.

This fifth volume of Prof. Baird's "Annual Record of Science and Industry" is not only the most voluminous, but also the most complete of the series. The first part of the work, comprising a brief narration of scientific and industrial progress during the year 1875, is specially valuable. Each principal branch of science and industrial art is here considered separately, and the reader is enabled readily to note the amount of progress made in each during the past year, and to observe the directions in which the thoughts of practical and scientific men are tending. Such annual summaries will, in future times, be of invaluable service to the historian. This portion of the work occupies nearly 300 pages. The second part consists of paragraphs communicating in brief the results of special scientific investigations. These paragraphs are distributed under the heads of "Mathematics and Astronomy," "Terrestrial Physics and Meteorology," "General Physics, Chemistry, and Metallurgy," "Mineralogy and Geology," "Geography," "General Natural History and Zoölogy," "Botany and Horticulture," "Agriculture and Rural Economy," "Pisciculture and Fisheries," "Domestic and Household Economy," "Mechanics and Engineering," "Technology," "Materia Medica," "Therapeutics and Hygiene," "Miscellaneous." The work is provided with a good index.

### Manual of the Apiary, pp. 59. Also, Injurious Insects of Michigan, pp. 48. By Prof. A. J. Cook, of the Michigan State Agricultural College.

In the first of these two pamphlets Prof. Cook aims to supply a want which has long been felt, that of a hand-book on bee-culture, which shall be at once simple in style, full in its discussions, low-priced, and up with the times. In all these respects he has undoubtedly attained a very fair measure of success. The injurious insects treated of in the second pamphlet are, the potato-beetle, May-beetle, pea-weevil, squash-bug, sundry enemies of the cabbage-plant, plum-curculio, grape-phylloxera, clothes-moth, etc.

### Standard Facts and Figures. Compiled by A. G. Sullivan. New York: Morton & Dumont. Pp. 109.

This little manual contains a large amount of commercial and financial information of special importance to business-men, and to those who desire to purchase Government, State, railway, and mining stocks. The volume also contains tables of interest, exchange, prices of gold, etc. The value of the work is much enhanced by a very complete index.

### Proceedings of the Poughkeepsie Society of Natural Science. Vol. I., fascicule I. Pp 41.

This installment of the proceedings of the Poughkeepsie Society of Natural Science consists of only one paper, by Charles B. Warring, entitled "Studies upon the

Inclination of the Earth's Axis." The author considers the following questions: How could a belt of nebulous matter acted on by the laws of motion and gravitation become a spheroid? How did the axis of the spheroid, normally perpendicular, become inclined? What was the amount of this inclination up to the moment of the earth's existence separate from the moon? When did the increase to the present obliquity occur? Finally, what was the cause of that increase?

Man: Palæolithic, Neolithic, and several other Races, not inconsistent with Scripture. By Nemo. Dublin: Hodges, Foster & Co. Pp. 137.

The first appearance of man upon the earth took place, according to this author, in the Pliocene, or perhaps earlier. . Before the Adam of the book of Genesis there were several creations of man, and of these creations ten races besides that of *Adam* survive to this day. Thus, instead of being the *first*, the scriptural Adam was the *last* created man. After the "six days" of creation the seventh day commenced, and of that day nearly 6,000 years have run. Judging from analogy, many thousands of years have yet to elapse before the "seventh day" is ended.

On Supposed Changes in the Nebula M 17 = h. 2008 = G. C. 4403. By E. S. Holden.

This paper, reprinted from the *American Journal of Science and Art*, goes over the same ground as the article by the same author, "The Horseshoe Nebula in Sagittarius," in Vol. VIII. of this Monthly. In the latter paper Prof. Holden addresses a popular audience, and he accordingly eschews mathematics; but in the former he addresses astronomers, and of course writes in technical language.

The Public-School Question: Two Lectures. Boston: Free Religious Association.

The school question is here presented from two opposite points of view: that of "an American Catholic citizen," by Bishop McQuaid, of Rochester, N. Y.; and that of "a liberal American citizen," by Francis E. Abbott, editor of the *Index*.

Wheeler's Survey of the Territories. Reports of G. K. Gilbert, pp. 270; Edwin E. Howell, pp. 70; and A. R. Marvine, pp. 35. Washington, 1876.

These reports have been printed by the authors for private circulation. They are all extracted from vol. iii. of Wheeler's United States Engineer Reports of Explorations and Surveys west of the One Hundredth Meridian. The authors, in this private edition of their reports, correct various typographical errors, and restore some passages which, though occurring in the original manuscripts, do not appear in the documents as officially published. In some instances statements made in the reports are corrected in accordance with the results of more recent investigation.

Memoirs of the Peabody Academy of Science, No. 4. Salem: Published by the Academy. Pp. 94, with Plates.

In this elegant quarto volume the Peabody Academy presents to the public the late Prof. Jeffries Wyman's memoir upon the fresh-water shell-mounds of the St. John's River, Florida. Prof. Wyman made his first examination of these shell-mounds in 1860, when collections were made at Lake Harney, Black Hammock, and Enterprise. In 1867 he revisited these places, and soon afterward published a short account of them, of which the present memoir is in some respects a reprint. But later he had opportunities for further exploration, the results of which are here given. The collections made by Prof. Wyman are preserved in the Peabody Museum of American Archæology and Ethnology at Harvard College.

Bulletin of the United States Geological and Geographical Survey of the Territories. Vol. II., No. 1, pp. 87; No. 2, pp. 100.

The first of these two numbers of the *Bulletin* of Hayden's Survey is specially interesting. It contains seven papers, nearly all of them illustrated, on archæological subjects connected with Colorado, Arizona, Utah, and other Western Territories. In number two are two essays, viz., "Studies of the American Falconidæ," and "Ornithology of Guadeloupe Island." Both of these papers are by Mr. Robert Ridgeway.

Contributions to the Natural History of Kerguelen Island. By J. H. Kidder, M. D. II., pp. 122. Washington: Government Printing-Office.

In this bulletin are embodied the results of an examination of the eggs brought from Kerguelen Island by the United States Transit-of-Venus Expedition, the identification of the botanical specimens, and determinations of the small but interesting zoölogical collections. The latter contain a large number of new genera and species, especially in mollusks, insects, crustaceans, and echinoderms.

Occurrence of Eozöon Canadense at Côte St.-Pierre. By J. W. Dawson, LL. D. Pp. 10, with Plate.

The controversy as to the true nature of *Eozöon Canadense*—whether it is of organic origin, or whether it is simply and purely a mineral formation—still continues. A short time ago we made mention of a paper by Otto Hahn, on the negative side of this question. In the paper before us Dr. Dawson presents with considerable force the arguments in favor of the organic origin of this curious fossil.

Bulletin of the United States National Museum, No. 5, pp. 82. Washington: Government Printing-Office.

In 1872, while on a visit to the Bermudas, Dr. G. Brown Goode, assistant curator of the United States Museum, studied the fishes of those islands. The present number of the *Bulletin* contains the results of Dr. Goode's studies. His "Catalogue of the Fishes of the Bermudas" names and describes seventy-five species of fishes belonging to Bermudan waters—most of them observed by the author himself. Up to the time of his visit, only seven species of fishes had been recorded from that locality.

Transactions of the Kansas Academy of Science. Vol. IV. Pp. 63. Topeka: Printed by G. W. Martin.

Contains twelve papers bearing the following titles: "Ozone in Kansas Atmosphere," "The Nebraska Hot Bluff," "Kansas Chalk," "Kansas Soils," "Kansas Salt," "Calamites," "Kansas Mammalia," "Habits of Certain Larvæ," "The Cottonwood-leaf Beetle," "Rocky Mountain Locust," "Sage Sphinx," "Lepidoptera of Eastern Kansas."

The Historical Jesus of Nazareth. By M. Schlesinger, Ph. D. Pp. 98. New York: Somerby.

Dr. Schlesinger, in the first place, analyzes the Messianic idea as it existed in the minds of the prophets and in the traditions of the people of Israel. He then examines the New Testament writings, in order to show what manner of man Jesus really was, and what religious and moral doctrines he held. These, according to the author, were purely Jewish—"Jesus was nothing but a Jew." The Christian system really originated with the apostle Paul, who boldly cut the new religion loose from its parent trunk, Judaism.

Bulletin of the Bussy Institution. Part V., pp. 97, with Plates. Cambridge: John Wilson & Son.

Of the seven papers contained in this volume three are on chemical subjects, viz., "The Composition of Date-stones," "Analysis of Potassic Fertilizers," "Occurrence of Ammonia in Anthracite." The author of these papers is Prof. F. H. Storer, dean of the institution. The other four papers are on botanical subjects, viz.: "A Disease of Olive and Orange Trees," "The American Grape-vine Mildew," "Fungi found in the Vicinity of Boston," and "The Black Knot." These papers are by Prof. W. G. Farlow.

Jansen, McClurg & Co. announce the publication of a "Manual of the Vertebrates of the Northern United States," by David S. Jordan. The work is designed to reduce the labor of classifying and ascertaining the names of specimens, and to fill in the study of zoölogy the place that Gray's "Manual of Botany" has long filled in the study of plants. 1 vol., 12mo, pp. 342. Price $2.

Under the title "Condensed Classics," Henry Holt & Co. will soon commence the publication, in condensed form, of a series of standard works of English fiction, the purpose being to save the time of the reader by eliminating those portions of the text that can be spared without impairing the continuity of the story. The work of condensation is in the competent hands of Mr. Rossiter Johnson. The initial work of the series will be "Ivanhoe," by Sir Walter

Scott. This will be speedily followed by "Our Mutual Friend," by Charles Dickens, which will be succeeded by "The Last Days of Pompeii," by Bulwer.

In the prospectus of the *Quarterly Bulletin of the Nuttall Ornithological Club*, it is stated that "papers received from resident and corresponding members of the club, together with such matter pertaining to birds as may be gathered from other sources, will make up the contents. It is proposed to issue 16 pages quarterly. Starting, however, with 28, we hope to receive sufficient aid to warrant the continuation of a like number, and to make the work at least self-supporting." $1 per year. Published by H. B. Bailey, 13 Exchange Place, Boston.

The *American Catholic Quarterly Review* takes the place of the defunct *Quarterly Review* edited by the late Dr. Orestes A. Brownson. The new periodical, however, will occupy a wider field than its predecessor, embracing within its scope not only theological, philosophical, and political, but also historical, scientific, and literary discussions. It has a strong editorial staff, and among its contributors are the foremost Catholic *littérateurs* and scholars of the United States and England. $5 per year. Philadelphia: Hardy & Mahony, 505 Chestnut Street.

## PUBLICATIONS RECEIVED.

The Logic of Chance. By John Venn, M. A. Pp. 488. New York: Macmillan. Price, $3.75.

Village Communities. By Sir Henry S. Maine. Pp. 425. New York: Holt & Co. Price, $3.50.

The Andes and the Amazon. By James Orton, A. M. Pp. 645. New York: Harpers. Price, $3.00.

Comparative Zoölogy. By James Orton, A. M. Pp. 396. New York: Harpers. Price, $3.00.

Elements of Physical Manipulation. By E. C. Pickering. Part II. Pp. 326. New York: Hurd & Houghton. Price, $4.00.

Ninth Annual Report of the Peabody Museum of American Archæology. Pp. 54.

Recent Advances in Physical Science. By P. G. Tait, M. A. Pp. 349. New York: Macmillan. Price, $2.50.

The Fatigue of Metals. By L. Spangenburg. Pp. 90. New York: Van Nostrand. Price, 50 cents.

Eighth Annual Report on the Insects of Missouri. By C. V. Riley. Pp. 186. Jefferson City: Regan & Carter print.

Seventh Annual Report of the Massachusetts Board of Health. Pp. 574. Boston: Wright & Potter, print.

Annual Report of the Louisiana Board of Health. Pp. 261. New Orleans *Republican* print.

Annual Report of the St. Louis School Board. Pp. 407. St. Louis *Globe-Democrat* print.

Report on the Ventilation of the United States Hall of Representatives. By Robert Briggs, C. E. Pp. 45. Philadelphia: H. B. Ashmead print.

Tenth Annual Report of the Trustees of the Connecticut Hospital for the Insane. Pp. 56. Middletown, Connecticut: Pelton & King print.

Centennial Newspaper Exhibition. Compiled by G. P. Rowell & Co. New York. Pp. 295.

Papers read before the Π Π Scientific Society of the Rensselaer Institute. Troy, New York. Pp. 44.

Normal Standard of Woman for Propagation. By N. Allen, M. D. Pp. 39. New York: W. Wood & Co.

The Wire-Ligature. By W. A. Byrd, M. D. Pp. 20. New York: Appletons.

Biblia Sacra Nova. Pp. 30. New York News Company. Price, 25 cents.

Catalogue of Isaac Lea's Published Works. Pp. 22. Philadelphia: Collins print.

Further Notes on "Inclusions" in Gems. By J. Lea, LL. D. Pp. 12. Philadelphia: Collins print.

Lateral Pressure of Rocks. By W. H. Niles. Pp. 15. Boston: Kingman print.

Notes on the North American Ganoids. By B. G. Wilder. Pp. 44. Salem Press. Price, 50 cents.

Distribution of the Geneva Award. By Hon. Elijah Ward Pp. 10. Washington, 1876.

Terre Haute Public Schools. Pp. 92. Terre Haute, Ind.: *Globe* Printing-Office.

Report on Dermatology. By L. P. Yandell, Jr., M. D. Pp. 7. Indianapolis *Journal* print.

The *Missouri Dental Journal.* Monthly. Pp. 16.

The Glacial Epoch and the Distribution of Insects in North America. Pp. 5. Are Potato-Bugs poisonous? Pp. 3. By A. R. Grote. From Proceedings of American Association for the Advancement of Science.

Nothing. By W. H. Boughton. Pp. 8. Brooklyn: E. S. Dodge print.

Chemistry of Three Dimensions. By F. W. Clarke. Pp. 9. From Proceedings of American Association for the Advancement of Science.

Experimental Proof of the Law of Inverse Squares for Sound. By W. W. Jacques. Pp. 8.

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## MISCELLANY.

**The Academy of Natural Sciences of Philadelphia.**—The Academy of Natural Sciences of Philadelphia having, at the beginning of the present year, taken possession of its commodious new building, Prof. E. D. Cope avails himself of the occasion to suggest in the *Penn Monthly* some needed changes and improvements in its organization. The objects of the Academy, as stated by its founder, are, the promotion of original investigation, the imparting of instruction, and the diffusion of knowledge. The Academy possesses a moderate fund for promoting the last-named object, and publishes its "Transactions" regularly. But the other two objects do not receive the same attention. Original research is not materially encouraged by the Academy, and in one instance funds, supposed to be devoted to research, were hoarded and afterward turned over to the building-fund. Less than five hundred dollars per annum is devoted to "instruction." The chief fault found by Prof. Cope in the organization of the Academy is that, while it secures good financial management, it minimizes the scientific features of the body. "Its officers are the usual president, vice-president, secretary, etc., constituting a management as appropriate to an historical society, library company, or, I might add, church vestry, as to an academy of natural sciences. It has no position designed for its distinctive and essential feature, its scientific experts."

Prof. Cope's remedy is simply to adopt the organization which is possessed by all similar institutions the world over. "Let it create as many positions as there is reasonable probability of receiving endowments in future years, and attach to them privileges which will render them desirable to incumbents, and duties such as are necessary to the Academy."

**Wyville Thomson on Oceanic Circulation.**—Prof. Wyville Thomson, in a report to the hydrographer to the British Admiralty, discusses the problem of oceanic circulation, and gives reasons for believing that the bottom water of the two great oceans is an extremely slow indraught from the Southern Sea. This indraught he refers to the simplest and most obvious of all causes, viz., the excess of evaporation over precipitation in the northern portion of the land hemisphere, and the excess of precipitation over evaporation in the middle and southern part of the water hemisphere. In concluding the report, Prof. Thomson further says, "I need scarcely add that I have never seen, whether in the Atlantic, the Southern Sea, or the Pacific, the slightest ground for supposing that such a thing exists as a general vertical circulation of the water of the ocean depending upon differences of specific gravity."

**The Discovery of Anæsthesia.**—Dr. H. P. Stearns, of Hartford, at the close of an able "Critique on the History of Modern Anæsthesia," which appears in the *Medical Record*, sums up in the following terms the results obtained by sundry prominent claimants of the honors of discovery: 1. In December, 1844, Wells made the suggestion and applied the test in his own person, by inhaling a large dose of nitrous oxide, and having a tooth extracted without pain. 2.

In September, 1846, Morton, a former pupil of Wells's, aware of his discovery and repeating his experiments, extracted a tooth without pain, while the patient was under the influence of sulphuric ether. 3. In 1847 Simpson first introduced the practice of anæsthesia in midwifery, thereby making known more widely its value. He also discovered the anæsthetic properties of chloroform, and by his writings and teachings very largely contributed to introducing the practice of anæsthesia to the world. 4. Others have since discovered the anæsthetic properties of different vapors, which are more or less used in practice.

**Loss of Self-Control in Battle.**—In his "History of the Civil War in America," the Count de Paris gives some curious instances of the loss of self-possession among soldiers in the heat of battle. He states that, among 24,000 loaded muskets picked up at random on the Gettysburg battle-field, one-fourth only were properly loaded; 12,000 contained each a double charge, and the other fourth from three to ten charges. In some there were six balls to a single charge of powder; others contained six cartridges, one on top of the other, without having been opened. A few had twenty-three complete charges regularly inserted. Finally, in the barrel of a single musket there were found, confusedly jumbled together, twenty-two balls and sixty-two buckshot, with a proportionate quantity of powder! "But we should not severly criticise the American soldier," adds the author, "for it appears that an examination of the battle-fields of the Crimea gave similar results."

**Pennsylvania Coal-Supply.**—The available coal of the Alleghany coal-field is estimated by Mr. Andrew Roy, in the *Engineering and Mining Journal*, at 743,424,000,000 tons, an amount nearly ten times greater than the estimates made by Edward Hull and Warrington Smith of the coal resources of the British Isles. The same writer states the aggregate thickness of workable coal in the anthracite regions of Pennsylvania as 200 feet in 2,175 feet of coal-measures. In the bituminous regions of Pennsylvania, near Pittsburg, he estimates 60 or 70 feet of workable coal to 2,000 feet of coal-measures. In West Virginia, where the Kanawha River cuts the coal-measures to their base, 78 feet thickness of coal in 16 seams is revealed; and along the Ohio, from Bellaire to Pomeroy, the proportion is 40 or 50 feet of coal in 1,200 to 1,400 of rock. The number of workable seams and consequent thickness of coal in every division of the coal-area are in proportion to the thickness of the carboniferous rocks. Beginning at the base of the coal-measures, and reaching up to the height of 400 feet, to the base of the barren measures, there exist, in the bituminous regions, 3 feet of coal for every 50 feet of strata. The next 400 feet are generally barren of workable coal; but from the Pittsburg seam, which is the lowest bed of the upper series, to the outcrops or top of the coal-strata, the same general estimate of 3 feet of workable coal to every 50 feet of rock will hold good.

**The People of Eastern New Guinea.**—Signor d'Albertis agrees with Moresby in describing the inhabitants of Eastern New Guinea as of materially different race from the true Papuans, who are found in the far west of the island. The people of Yule Island, and of the coasts east and west of it, resemble those of the Polynesian region in many respects. The indigenous Papuans, physically and morally inferior to these Polynesian invaders, have been driven from the coast, where the land is comparatively healthy and fertile, and have permitted the intruders to establish themselves and multiply. The inhabitants of the interior are darker in color, the hair is more frizzed, and there is a difference in the form of the face, the prognathous appearance being more common than on the coast. From what D'Albertis has seen of the interior, he concludes that the land is very suitable for colonization, being well watered, with abundance of grass, and having a good climate without excessive heat. The natives are described as "intelligent, industrious, and persevering."

**Body Temperature of the Drunkard.**—Observations made by Dr. Reincke, of Hamburg, on eighteen drunken men, leave no doubt as to the great reduction of temperature in such persons, when the external conditions favor the withdrawal of the bodily heat. Alcohol produces a dilatation of the peripheral vessels, whereby more blood enters the skin and contributes to raise its temperature. If the body be well clothed and protected from external influences likely to abstract heat, the reduction of its warmth is inconsiderable; but if exposed to cold and placed under circumstances favorable to the abstraction of heat, there is a rapid loss of warmth from the blood circulating in the skin. The lowest temperature met with by Reincke — lower than in any recorded instance in which the individual survived—was the case of a man thirty-four years old, picked up in the street about midnight in February, when the temperature of the air was 30° Fahr. He was in a state of complete alcoholic coma, responding to no stimulant. At 8 A. M. his temperature, *in recto*, was only 75°, but at 12 M. it reached nearly 82°. At this period reaction began to show itself, and he could mutter a few words. From this point the heat of the body gradually increased and had reached the normal point the following morning.

**Houses for the Industrious Poor.**—The problem of cheap and commodious housing for the worthy poor continues to occupy the attention of philanthropists. We have already made mention in these columns of the bequest made by the late George Peabody for the erection of improved tenement-houses for the industrious poor of London. The trustees of the Peabody fund have recently completed twelve of these buildings, capable of accommodating 1,000 persons. In each building there are twenty-two tenements, consisting of one, two, or three rooms, with a separate entrance for each. The rooms are of good size, those of the three-roomed tenements being as follows: Kitchen, fifteen by twelve feet, a bedroom, sixteen by fourteen feet, second bedroom, sixteen by twelve feet, the rent being 5*s.* 9*d.* per week. The rent of a two-roomed tenement is 4*s.* 6*d.*, and for one room 3*s.* There are several cupboards and a meat-safe inside, and a coal-bin in the passage outside. On each flat is a laundry with every convenience; this is used by the tenants in turn. There is also a bath. The rules to be observed by the tenants are but few in number, and intended merely to secure cleanliness and good order. No one is allowed to occupy these buildings who earns more than thirty shillings per week.

**Present Condition of the Suez Canal.**—M. de Lesseps, on his return to Paris, after a five months' visit to Suez, communicated to the Académie des Sciences the details of his observations upon the present state of the isthmian canal. Port Saïd he found to be in no danger at all of being filled up with sand. The dredging-machine suffices to keep the channel clear. Moreover, it does not fill up so rapidly as has been supposed, for the work done last year still remains, and two very large ships have recently navigated the canal without difficulty—one of them drawing over twenty feet of water. In winter the current of the canal sets in toward the Mediterranean, owing to the excess of water in the Bitter Lakes; in summer the current is in the opposite direction. Since the construction of the canal there are frequent showers on the Red Sea, whereas, previously, rain was unknown there—a very extraordinary thing indeed, if it can be shown to be a fact. This rainfall, says M. de Lesseps, has started vegetation even on the Asiatic shore of the Red Sea, where the infiltration is only of salt-water.

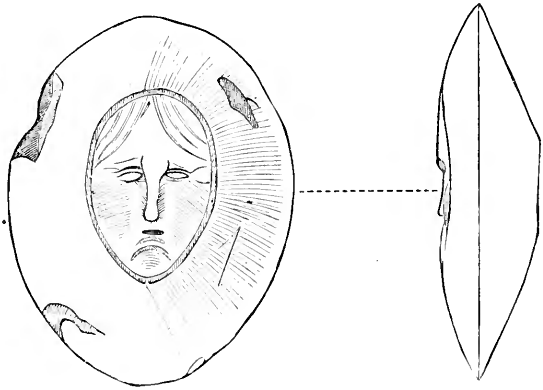
**Prehistoric Relics at the Centennial Exposition.**—Mr. Ernest Ingersoll, natural history editor of *Forest and Stream*, has commenced in that journal a series of letters on the Philadelphia Exhibition. In his first letter he describes the collections of American prehistoric relics exhibited by the Smithsonian Institution and by various States, especially Ohio. For the purposes of general illustration, the Smithsonian collection he pronounces the best; but the State collections possess greater interest for the archæologist, as embracing many unique objects, only casts of some of which are to be found in the Smithsonian display. In the Ohio collection, the first object which attracts attention is an immense axe of greenstone, sixteen and a half inches long. The arrow-heads and spear-points—chiefly of chalcedony—are remarkably fine. A few of these are made of obsidian, which must have been brought from Mexico. Articles of mica are there also, which must have been imported from a distance. The ornaments of the mound-builders are well represented, and include a variety of forms, all cut out of a blue Silurian slate-rock. Pipes of both the modern Indians and of the mound-builders are shown, the latter always carved in the form of some animal. One case contains a lot of awls, needles, and arrow-points, of bone and bear's teeth, upon which rude carvings are executed. There are also several human skulls in good condition. There are numerous photographs and maps of the enormous structures erected by the mound-builders throughout the Ohio Valley and northward.

**Winter Fauna of Mount Marcy.**—While engaged last winter on the survey of the Adirondack region, Mr. Verplanck Colvin made some observations upon the winter fauna of Mount Marcy, and has since read a paper on that subject before the Albany Institute. Among the most important of the animals whose footprints were found in the snow was the panther (*Felis concolor*). Rabbit-tracks which accompanied the panther's trail indicated that the "mountain lion" had been in pursuit of small game. Next in importance to the panther in the list of species, the trails of which were observed, was the Canada lynx; this animal, too, had been rabbit-hunting. The footprints of the black cat (*Mustela Canadensis*) were frequently met with, associated with the tracks of rabbits and even of mice. The sable (*Mustela martes*) is abundant in the forests on the sides of Mount Marcy. Tracks of the ermine (*Putorius noveboracensis*) were recognized in one place, but the animal does not seem to be common. The rabbit, or, more properly, the white or varying hare (*Lepus americanus*), is so abundant as to bear the inroads of its many foes without apparent diminution. The common red squirrel (*Sciurus hudsonius*) was found at an altitude of about 4,000 feet; it feeds here on the seeds of the black spruce. On the slopes of the mountain, at all elevations not exceeding 4,000 feet, were seen the tracks of deer-mice, and occasionally the minuter trail of a small shrew. Of birds three varieties had left their footprints in the snow—the raven, the ruffled grouse, and the snow-bird. During a thaw in October a small moth was captured on the summit of the mountain; it has been recognized as belonging to a species abundant in Alaska. During the same thaw a beetle was found upon the very summit of the peak.

**Eucalypti as Timber-Trees.**—There are in Australia a number of species of gum-trees, or *Eucalypti*, the best known being the *Eucalyptus globulus*, or blue gum. As timber-trees their properties differ widely. The tewart, a variety of the white gum-tree, is of straight growth and noble dimensions. The wood is yellowish, hard, heavy, and strong, with a grain so twisted and curled that it is difficult to cleave or work it. This wood is very durable. The wood of the jarrah (*Eucalyptus marginata*) is much used for telegraph-posts and railroad-ties. It defies the white ant and teredo, and is practically unaffected by time, weather, or water. The kari (*Eucalyptus diversicolor*) is a magnificent tree, but the timber is subject to "star-shake." The iron-bark (*Eucalyptus resinifera*) produces timber that is very hard, heavy, and strong. It is very difficult to work. The wood of the blue gum is of a pale straw-color, hard, heavy, but only moderately strong. It is a durable wood, but its value is much discounted by its tendency to split. The stringy-bark (*Eucalyptus gigantea*) is a lofty tree; the wood is brown, hard, heavy, and strong. It is used for all kinds of work.

**Concrete Construction.**—One of the most interesting features of last year's International Exhibition, at London, was the show of buildings of concrete in course of erection. One exhibitor showed a building, the material of which was concrete, faced with tile and terra-cotta mouldings. In this case the tiles are arranged in a supporting frame in their proper position, and concrete is then filled in behind. The cost is stated to be about the same as the best brickwork. As regards the strength of concrete constructions, Mr. W. C. Homersham, C. E., states that the staging necessary for carrying a concrete floor, in the green or wet state, of a room say twelve and a half by twenty-five feet, may be struck in a week after the completion of the floor, if the concrete be only six inches in uniform thickness, and gauged in such proportions that every cubic yard when *in situ* contains four bushels of Portland cement, and six bushels of clean, sharp, siliceous sand. One month after the concrete has set, the floor would be capable of sustaining an equally-distributed load of 112 pounds to the foot superficial, and, twelve months after, an equally-distributed load of 450 pounds per foot superficial. If the thickness of the flooring be increased to twelve inches, and the concrete gauged as before, a room nineteen and a half feet in width by any length may be covered with the same results as to strength, as those given above for the room twelve and a half feet in width. A wall of concrete is impervious to water, and fire-proof.

**A Relic of the Mound-Builders.**—Through the kindness of Prof. A. E. Dolbear, of Tufts College, Massachusetts, I am enabled to present to the attention of archæologists a brief notice and figure of an unusually interesting specimen of carving in stone, the work of the mound-builders of Ohio. The history of the specimen, as given me by Prof. Dolbear, is briefly this: "It was ploughed up in a field a few miles from Marysville, Union County, Ohio."



The relic is a small pebble of bluish-gray slate, highly polished, and ground to a moderately sharp edge. The front or carved side is oval and of a uniform surface; the back is sloped from a central flat, oval space, about one-fourth of an inch in its long diameter. Had the specimen not the carving of a face upon it, it could properly be classed with that form of implement known as the "celt," although these very seldom have an edge extending along the entire margin. Circular celts or "skinning-knives," of about the same size, with a cutting-edge along the whole margin, have been found by the writer, in New Jersey.

The remarkable feature of the relic here described is the human face carved upon one side. As a representation of a woman's face, it is certainly artistically executed. As has been remarked of a mound-builder's smoking-pipe, having a somewhat similar carving,[1] "the muscles of the face are faithfully rendered, and the forehead is finely moulded. The eyes are prominent and the chin open, and full and rounded." The nose and mouth are distinctly cut, but not as accurately finished as the other features.

Although the labor expended upon the stone to bring it to so well defined an edge, about its margins, was so considerable, the specimen can scarcely be considered an ornamented cutting-implement. Celts, such as we have referred to, are never marked by carvings, even of plain lines, so far as we have collected them in New Jersey; although some other forms, as plummets (?) and pesties, were occasionally carved. What, indeed, this relic really was, when the aborigine who carved it had it in possession, it is useless to conjecture. Its value now consists in its being a well-preserved specimen of the work of a stone-age savage; and possibly a characteristic delineation of the features of a woman of the race known as the mound-builders.

Charles C. Abbott, M. D.

**The Loan Exhibition in London.**—The exhibition of scientific instruments at London was opened with an address by Mr. W.

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[1] "Flint Chips," p. 433, American edition.

Spottiswoode, F. R. S., who, after calling attention to the great number of antique instruments present, dwelt upon the valuable services often rendered to science by earnest students possessed of very inadequate means. "In reviewing," he said, "the series of ancient, or, at least, now disused instruments, one thing can hardly fail to strike the attention of those who are accustomed to the use of the modern forms. It is this: how much our predecessors managed to achieve with the limited means at their disposal. If we compare the magnificent telescopes, the exquisite clock-work, the multiplicity of optical appliances now to be found in almost every private, and still more in every public observatory, with those of two centuries past; or, again, if we look at the instruments with which Arago and Brewster made their magnificent discoveries in polarized light, in contrast to those with which the adjoining room is literally teeming, we may well pause to reflect how much of their discoveries was due to the men themselves, and how comparatively little to the instruments at their command.

"And yet we must not measure either the men or their results by this standard alone. The character of the problems which Nature propounds varies greatly from time to time. First we have some great striking question, the very conception and statement of which demand the highest powers of the human mind. Next follow the first outlines of the solution sketched by some master-hand; afterward the careful and often tedious working out of the details of the problem, the numerical evaluation of the constants involved, and the reduction of all the quantities to strict measurement. It is in this part of the business that the more elaborate instruments are specially required. It is for bringing small differences to actual measurement that the complex refinements with which we are here surrounded become of the first importance. But happily this complication is not of perennial growth. In reviewing from time to time the various aspects of a problem in connection with the instrumental appliances designed for its solution, the essential features come out by degrees more strongly in relief. One by one the unimportant parts are cast aside, and the apparatus becomes reduced to its essential elements."

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# NOTES.

The Franklin Institute of the State of Pennsylvania has opened a reception-room at the northwest end of the Machinery Hall, Centennial Exhibition grounds. The following objects of great historical interest have been placed in the room: 1. Franklin's electrical machine; 2 Oliver Evans's steam locomotive-engine, constructed in 1804; 3. Oliver Evans's high-pressure steam-engine, same date; 4. Working model of a steam-engine constructed by M. W. Baldwin, presented by him to the Franklin Institute, about the year 1832. Files of the industrial journals may be found here, and visitors will be cordially welcomed.

Preliminary steps have been taken for holding an international horticultural exhibition and botanical congress in London in the year 1879.

A report made to the Silk-Merchants' Union of Lyons states the silk-crop of Europe in 1874 to have been, in round numbers, 9,050,000 pounds. The silk imported into Europe amounted to 11,500,000 pounds, most of it (8,000,000 pounds) coming from China. The greater part (6,000,000 pounds) of the domestic silk was produced in Italy.

A course in Herbert Spencer's "Principles of Psychology" will be given at Harvard University during the year 1876–'77, under the instruction of Prof. James.

In the *Pacific Medical and Surgical Journal* a case is recorded of the conveyance of small-pox in a letter from Indiana to California. A man in the latter State received last December a letter from a sister in Indiana, stating that four members of her family had small-pox. A few days after the receipt of the letter, the man became ill, and the disease developed into a well-marked case of discrete variola.

In the sugar-plantations of Natal the large python is employed to keep down rats and mice.

At a late meeting of the St. Louis Academy of Science, Prof. C. V. Riley exhibited cocoons and spinning worms of the common mulberry silk-worm (*Sericaria mori*) reared on Osage Orange. The worms were a cross between the best French and Japanese races, and he had reared them for five years on Osage Orange with no reduction in quantity or quality of silk, and great increase of vigor and healthfulness.

Macmillan will publish in the fall two volumes by Prof. Wyville Thomson, on the "Results of the Challenger Expedition." This work will be illustrated by drawings, made on the spot by Mr. Wild, the artist of the expedition, of the many curious and beautiful creatures now for the first time brought to light.

A new grape-fungus, which first appears on the leaves of the grape-vine, in the form of a minute yellow spot, was described by Dr. Engelmann, at a recent meeting of the St. Louis Academy of Science. It makes its appearance just before and during the flowering period, as far as known attacking only the leaves, or rarely the petioles and peduncles. It kills the leaves, and thus cripples the plant, and attacks all varieties indiscriminately.

A set of wheels was lately taken from beneath the baggage-car of the California and Oregon express train at Sacramento, which had traveled in daily use 91,800 miles, nor were they worn out even then, but had become loose on the axle.

The Challenger Expedition returned to England May 23d, after an absence of three years and five months. During that time the vessel sailed 61,840 miles. The number of soundings made was 370, of dredgings, 360. Some hundreds of specimens were sent home during the voyage. The mortality was not above the mean, and, when it is remembered that the average time at sea was 220 days per year, it is surprising that the health of those on board (259 in number) was as good as it was.

During the thirty years, 1841–'70, the death-rate of England and Wales was nearly stationary, about twenty-two per thousand. It must not be supposed, however, that in the mean time no progress was made in sanitary science. The rapid development of manufactures led to the crowding of people in towns, and this must have tended to produce a higher death-rate. The local statistics strikingly exhibit the influence of this massing of people in manufacturing and mining centres. For instance, while Cambridgeshire shows a progressive decline of death-rate, in the West Riding of Yorkshire, where the urban population has been enormously increased, the death-rate has been steadily rising.

A street-pavement of pig-iron is soon to be tried in Paris. In constructing a roadway of this kind, a bed of mortar is first laid down, which is covered by a strong layer of asphalt; it is in this layer that the iron cakes, which are about 1.6 inch thick, are set. These cakes, it appears, preserve the homogeneity of the bitumen and prevent its depression, and render the asphalt less slippery for horses. This pavement will cost more than the compressed asphalt, but it is estimated that it will save 50 per cent. of the repairing expenses, which are very considerable. The end desired is to avoid, by the adoption of this kind of pavement, the depressions in roads over which a great deal of traffic passes. To attain this, it does not suffice to pour bitumen upon a well-prepared ground lightly covered with a coat of lime; the resistance of the ground should equal that of an old macadamized bank; and a very thick bed of mortar, which should be very homogeneous, should be laid before the asphalt.

A new process of gas-manufacture has been patented by Malam, manager of the Dumfries (Scotland) Gas-Works. The advantage claimed by the inventor for the new process is, that a large proportion of the liquid hydrocarbons, which would otherwise go to form tar, are converted into gas, and thus an increased production of gas is insured to the amount of 3,000 or 4,000 feet per ton, while the quality is not deteriorated.

In announcing the sale of the Hoosac Tunnel machinery, the *Engineering and Mining Journal* remarks: "The contractors completed, in the most satisfactory manner and it is said at a considerable pecuniary sacrifice, a most difficult work (the tunnel), and one which is of considerable advantage to the State (Massachusetts), and it is greatly to be regretted that the government of a great State should resort to those devices, to avoid the fair and honest performance of their engagements, which, when practised by individuals, are characterized as 'tricky' and 'dishonorable.'"

Water which has been kept for some time in the state of ebullition does not make so good an infusion of tea as water "just upon the boil." A reason for this is suggested by a writer in the *Chemical News*, who says that the escape of dissolved gases might possibly account for the inferiority of tea-infusion made with long-boiled water. To test this, he passed for ten minutes through boiling water a stream of carbonic-acid gas, and then made an infusion of tea with it. The result was decidedly better than when water was employed that had boiled for the same length of time without the addition of the $CO_2$.

The depth of the Pacific Ocean between Hawaii and Tahiti, as developed by the soundings of the Challenger Expedition, ranges from 2,000 to 3,000 fathoms, with one exception of 1,525 fathoms. The bottom, except near the islands, is mainly red clay, with much oxide of manganese in small concretions and many foraminifers.

WILLIAM BARTON ROGERS.

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# VOICE IN MAN AND IN ANIMALS.[1]

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## II.

IN all languages there exist sounds—vowel and consonant—represented by the letters of the alphabet. This, in the opinion of some linguists, is an evidence of a common origin, while naturalists hold it to be the inevitable effect of the functions of an organ whose conformation scarcely differs in any perceptible degree between one race and another. Nevertheless languages differ very much in the number of their intonations. If, in this respect, the languages of uncivilized nations stand lowest, it does not necessarily follow that the languages of the most highly-civilized peoples must hold the highest rank. The Hindustani is distinguished by an unparalleled abundance of consonants; the Semitic languages surpass the Greek and Latin, as also the languages of modern Europe; the dialects of Polynesia afford instances of the greatest poverty of consonant sounds. Of the Hurons and Mohawks of North America, who habitually kept the mouth open, it is asserted that they knew nothing of the use of the labials—articulations so natural to us that we might be disposed to regard them as instinctive. Sundry nations eschew the use of hissing and trilling sounds;[2] others have no gutturals. Some years ago, preferences for harshness or for softness of language seemed to us to show that neither the vocal organs nor the auditory perceptions are absolutely identical in all races of mankind;[3] this is now rendered more probable by multiplied observations and experiments. We know how great is the difficulty of rendering certain sounds in a foreign language, and hence it is that words change in migrating from place

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[1] Translated from the French by J. Fitzgerald, A. M.

[2] *f, s, z, l, r.*

[3] "Voyage au pôle sud et dans l'Océanie;" "Anthropologie," par M. Émile Blanchard," 1854.

to place. The Chinese invariably substitute the soft for the hard trill,[1] and this substitution is common among other nations. The Polynesians put gutturals in the place of dentals,[2] and the missionaries who are educating the youth of the Hawaiian Islands have had to abandon sounds that the people are unable to pronounce. It is almost as difficult rightly to hear as it is correctly to imitate articulations foreign to one's own tongue: travelers hardly ever agree in their representations of names that they have heard pronounced by natives. Are differences of voice and of auditory perception the result to a small extent of organization, but to a greater extent of early education? One is tempted to believe that such is the case. But experiment and observation, hitherto very limited, have not yet thrown upon this subject the light of scientific truth.

Words are formed by the combination of vowels and consonants; the voice gives utterance to them; this is language which is at first governed by convention, and then by grammar. Pronunciation results from the emission of articulate sounds; its range in pitch is usually about one-half of an octave. Commonly the voice rises or falls a little at the end of a phrase, producing accent, or marking affirmation or interrogation. The adult man, as a rule, speaks in the lower register, children and women in the upper register, but to this there are many exceptions.

Though we all employ speech, yet we differ in ease and agreeableness of utterance. The voice is weak or powerful, as determined by the mode of action of the respiratory organs. The timbre is sharp, harsh, sweet, or harmonious; this is determined by the conformation of the resonant cavities. Whatever quality of voice we happen to have naturally, is to be preserved, though it may be improved by constant attention to the ear, by steady observation, finally by training. Speech does not flow from its source with the same ease in all cases: here the mind is master, and mental qualities differ from one another to a far greater extent than physical aptitudes. Some persons express themselves without difficulty or hesitation—their thinking faculty acts as a continuous force; others seem to grasp a word or a phrase here and there—their thinking faculty is fluctuating, confused, undecided. A certain feeling of constraint produces stuttering, stammering. It used to be supposed that stuttering is the result of grave defects of the vocal organs, but such is not the case at all; this infirmity has its seat in the mind, and it may be cured or mitigated by systematic effort. It is shown by statistics that Provence, Languedoc, and Guienne, contain a greater proportion of stammerers in their population than any other portions of France.[3] This statement, when

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[1] *l* for *r*—*Eulope* for *Europe*.

[2] *gh* for *d*, *k* for *t*. This change of pronunciation is not infrequent in some country districts of France.

[3] "Statistique décennale du bégaiement en France," par Chervin aîné, Lyon, 1866.

first I saw it, was a surprise to me; it has always been thought that no one could possibly falter in his speech who was born near the Garonne.[1]

In performing its great function of establishing all the social relations between man and man, the voice readily calls forth sympathies and antipathies; its quality reveals better than words the true feelings of the heart. A voice that is clear, pure, limpid, conveys the impression of frankness; one that is hesitating, drawling, betokens dissimulation; a harsh, grating voice indicates an evil disposition; while a voice that is sweet, harmonious, affects us as though it were the breathing of a gentle soul. These impressions made by the voice are usually correct, and rightly enough influence the relations of man to man, still we must not trust them too implicitly. No doubt language may serve to disguise thought, but the vocal instrument itself may also produce false impressions. Besides the effects of Nature, we have the effects of art. An orator wishing to make himself heard, or to produce a sensation, opens his mouth widely, and derives from the resonant cavities all the aid that they can supply; this is the declamatory style, condensed by good taste. If the mouth be opened very widely, and the breath emitted with force, the voice becomes imperious: such is the tone in which a military officer gives the word of command. Words that are in themselves simple enough, when uttered in a hard, brusque tone, become offensive. When the sounds are uttered softly, with some degree of tremulousness, the words succeeding one another with deliberate slowness and imperceptible lowering of pitch, the sympathy of the hearer is awakened. Some women, it is asserted, possess a wonderful power of thus rendering their entreaties irresistible. Historians affirm that Cicero's graceful utterance added greatly to the persuasive force of his words. The orator who possesses a good voice, and who can at will assume the tones that best agree with the sentiments, emotions, and passions, which he would arouse, will win the hearts of his auditors, whereas the grandest oration delivered by an unpractised speaker would fail to move them.

Singing requires of the vocal organs functions very different from those required for speaking. Furthermore, a good physical constitution and perfect regularity in the functions of the organism, are of inestimable value to the artist. In the emission of the voice the respiratory movements must be performed without strain or effort; they must be so regulated as to make the inspiration short and easy, and the expiration slow and prolonged. There is a struggle between the organs which retain the breath and those which expel it; practice, youth, and good health, are the conditions upon which an adjustment must be based. In the highly-gifted artist the larynx holds its ordinary position notwithstanding the variations of intensity and pitch of

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[1] Memory and the faculty of coördinating words depend upon the brain. It appears, from Broca's researches, that these faculties are destroyed by a lesion of the third frontal convolution of the left side.

the sounds produced. Being implicated in some of the more energetic movements of the tongue, it rises or falls, but to no purpose. The larynx of the singer, while fixed in its position, multiplies its performance; the suppleness of all its parts is a matter of prime importance. The vibrations of the vocal lips and the resonance of the vestibule determine the timbre of the glottic sounds; the configuration of the pharynx and of the buccal cavity, by modifying the sounds formed in the glottis, produces the timbre of the voice. This cannot be altered to any considerable degree by even the most powerful efforts of the will. Professors of singing injure their pupils by prescribing in too absolute a manner the mouth arrangements which they themselves find most serviceable. Each individual must follow Nature, and M. Mandl had good reasons for begging singing-masters never to forget this truth.

Our ear is not affected by all sounds; those which are very low or very acute are not perceived. The limits of hearing are usually set at forty, and at forty thousand vibrations per second. Persons of extreme sensibility are not restricted within these limits, but their gift is not a source of pleasure; every one knows how painful it is to hear sounds that are too acute. Song is the result of modulated sounds separated from one another by harmonic intervals. The whole series of sounds from the grave to the acute is the musical scale; the voice has a greater or less range in different individuals. In the language of musicians, each series of consecutive and homogeneous sounds is a register; we have the chest-register, the head-register, etc. A strange idea has gone abroad: singers, being led astray by the resonance of the arch of the palate, and by certain peculiar sensations caused by the action of various muscles, have supposed that the voice comes now from the chest, again from the head. But, as every one must now be aware, voice is produced always in the glottis. Hence it were well, as M. Mandl advises, to abandon the use of terms which had their origin in a misapprehension, and to use instead of them the terms *lower* and *upper register*.

Singing requires far more precise arrangements of the vocal organs than does speaking. At the moment of producing the sound the glottic orifice should be absolutely shut; the voice-emission will be good provided the vocal lips go apart to the proper extent with a kind of suddenness. It is interesting to follow with the eye, by means of the laryngoscope, the play of the instrument in producing successively low and high notes. In producing very low notes the glottic orifice assumes the form of a very long, regular ellipsoid, with both extremities pointed; as the sound rises in pitch, the vocal lips at once approach each other, and the orifice, constricted at one point, appears to be divided into two parts; the pitch still rising, the uttermost limit of the register is attained, and then the glottic orifice becomes a linear slit. Passing to the upper register—the head-voice or falsetto—a curious change takes place suddenly in the configuration of the glottis: it appears to be absolutely shut below and open above. In proportion as the orifice is narrowed, the sound grows higher. The singer recognizes the registers by the ear from the timbre, the physiologist by the eye; for the latter, one of the registers consists of the series of sounds produced by the glottis when open along its entire length, the other register represents the series of sounds given forth by the glottis open through only a limited portion of its orifice.

The ordinary limits of the voice include about two octaves of the musical scale; by practice one can easily attain 2½ octaves, but a compass of three octaves, and especially of 3½ octaves, is very exceptional. Hence, at the beginning of the present century, Catalani was regarded as a sort of prodigy. In classing voices according to pitch we recognize three kinds of voice in men, viz., bass, barytone, and tenor, and three in women, contralto, mezzo-soprano, and soprano. Bass voices rarely fall below 173 vibrations, and soprano seldom exceed 2,069 vibrations per second. Still there have been deep voices which produced the note corresponding to 87 vibrations, and acute voices which attained as many as 2,784. The most famous cantatrices of our day are instances of this.[1] The different types of voice are characterized no less by their timbre than by their range. Voices present so many varieties, they are so *personal*, that thorough classification is almost impossible. Endless shades of difference are produced by the degree of intensity of the harmonics: if the intensity is great, the voice is brilliant, mordant; if feeble, the voice is soft, sombre. In the larynx itself, and in the trachea, there occurs a resonance, the effects of which have not yet been determined. In bass voices they are very noteworthy. The famous Lablache would have been an excellent subject for experiments by physiologists.

Having ascertained all the functions of the vocal apparatus, and accounted for the origin of the sounds of speech and singing, we may well be proud of the advance made by science, yet we cannot but be chagrined to think that it is not in our power to determine to what peculiarities of organic conformation the different kinds of voice are to be attributed. All that we can affirm with certainty is, that the sound produced is acute in proportion to the shortness of the vocal cords. One might be inclined to believe that the larynx is more voluminous in bassi than in tenori, in contralti than in soprani; but this is not universally the case. We cannot determine either the compass or the quality of a voice from seeing the instrument. The elasticity, suppleness, and contractility of the tissues, must have an immense in-

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[1] In general the bass voice extends from $\text{fa}_1 = 173$ vibrations to $\text{re}_3 = 580$ vibrations; the barytone from $\text{la}_1 = 217$ vibrations to $\text{fa}_3 = 690$; the tenor from $\text{re}_2 = 290$ vibrations to $\text{si}_3 = 976$; the contralto from $\text{sol}_2 = 387$ to $\text{fa}_4 = 1{,}381$; the mezzo-soprano from $\text{si}_2 = 488$ to $\text{la}_4 = 1{,}740$; the soprano from $\text{ut}_3 = 517$ to $\text{ut}_5 = 2{,}069$ vibrations.

fluence on the glottic sounds, and we possess no means of measuring these qualities.

The character of the voice is fixed from the time when the larynx has reached its full development. So long as the activity of youth continues, the voice will retain this character without any very considerable modification; still, by exercise it will perhaps gain intensity, and may be improved in point of timbre. Suppleness and agility of the organs are acquired only at the cost of labor; this is shown from the history of many a singer. The voice of the young Marie Garcia was at first harsh and husky, but afterward it became the sweet voice of Malibran. Still, as a rule, natural physical gifts manifest themselves prior to any attempt at culture.

As old age approaches, the play of the larynx becomes difficult; at first the tone of the voice is lowered, and then its intensity is lessened; the breath comes with less force. Sometimes disease impairs the instrument before the advent of age. While appearing to be intact, the organ often ceases to discharge its functions perfectly, owing to more or less serious affection of the nervous action. Mandl has, by means of electricity, momentarily restored voices that had been thus destroyed. Songstresses have now and then irretrievably lost their voices in consequence of overstrain of the vocal organs. Here we are reminded of the case of Cornelia Falcon.

Amid the refinements of civilized life, singing is prized only in so far as it is an art; when it rises to that dignity, it attracts crowds. A man or a woman possessing no matter how fine a voice, must begin by going to school. The instrument, whose admirable mechanism we have seen, is not entirely under control, except after much study and long-continued and methodical exercise. This is true of all organs subject to the will, as every one knows from experience, as in the employment of the hands. Though expert in all the movements of the larynx and the mouth, the singer cannot, even with a superb voice, produce brilliant effects, save by the aid of mind. From mind alone come expression, taste, style, and these qualities are all personal. Sensibility, whether real or feigned, is always an element of success. The artist is advised never to give way to the passions which he expresses, for mental commotion is quickly succeeded by extreme fatigue; he may attain a perfect imitation of passions, meanwhile preserving a tranquil mind. Still, are not emotions which are felt always the most communicable?

After we have studied the human voice in its various manifestations, the voice of animals seems to us to be scarcely worthy of notice. The barking of the dog, the mewing of the cat, the bleating of the sheep, undoubtedly constitute a very scanty language. These cries of animals do but annoy us; but it must be remembered that they are intended for other ears than ours. The warbling of small birds alone affords us pleasure; it possesses resemblances which cause pleasing illusions; it seems to express feelings common to ourselves, and hence we like it. The interest attaching to a comparison of the vocal apparatus of animals with that of man has long been appreciated, and the hope has been entertained of being able to explain the nature of all kinds of voice by studying the structure of the organs. Toward the end of the last century, Vicq d'Azyr attacked this problem. Having collected larynges of a number of animals, he regarded them with a sort of enthusiasm; he expected to get from them a revelation. "It is a fine spectacle," said he, "to see at a glance the structure of those infinitely-diversified instruments with which each animal produces its own proper modulations, thus contributing to Nature's grand concert."

The anatomical characters of the vocal apparatus are now pretty well known as regards most of the mammalia. The larynx of these animals is formed upon the same plan as that of man; in monkeys, the resemblance is extreme. The impossibility of speaking is due, as we have reason to suppose, to the conformation of the buccal cavity, the lips, and the tongue. The studies of naturalists, which as yet have not been directed to this point, do not warrant any positive statement: nevertheless, the power possessed by some species of pronouncing one or two syllables justifies a presumption. Does not this vestige of speech indicate the very limited extent of a faculty, not even a trace of which is found in most animals. In 1715 the great Leibnitz announced to our Academy the existence in Meissen of a talking dog, "a peasant's dog, of the most ordinary appearance, and of medium size." This extraordinary animal had learned, says the narrator, some thirty words; these it would repeat after its master. The historian of the Académie des Sciences declares that he would not have ventured to state such a fact "without such an authority as M. Leibnitz, an eye-witness." But, despite so high an authority, the story is a fable. Of the most intelligent dog we still must say, "All he lacks is speech." Were it not that Nature raises an obstacle, surely monkeys that live in the company of man would make the attempt to speak. We must conclude that their intelligence does not incline them toward this sort of imitation, and that their organs are not adapted for articulation.

It is a curious and very interesting fact that, before receiving instruction of any kind, young deaf-mutes who live together quickly discover means of understanding each other, so that they hardly ever misinterpret the feelings and wants expressed by the gesticulations, touches, and facial-muscle action, agreed upon. This instance of a convention between individuals not possessed of the power of employing language of necessity carries our thoughts to the actions of certain animals. The mammalia have a voice that is susceptible of inflexions and intonations more or less diversified according to the species; these they employ in making known to each other their appetites, their wants, to call one another, to announce to one another their presence. It is often said that animals possess only cries, but this statement is too general. The cat says *miau*, which is a very plain articulation of a labial consonant and three vowels; the word is well formed, and one might suppose it to be Chinese. The cat pronounces this word in many different ways, each having a meaning. If he wants company, he announces his presence in a strong voice; if he wants to be fed, or to have a door opened, his voice is soft and gentle; here is the accent of entreaty. If there is any delay, the tone grows higher, showing impatience. There is a slow, weak *miau*, which the French translate into "Comme je m'ennuie!" ("*How weary I am!*") and again there is the wheedling *miau*, full of pretty modulations, showing plainly a wish to please. Further, the cat says very distinctly *ronron*, a genuine word formed of trills and nasals; here the tongue and the soft palate perform movements which we know from our own experience. This *ronron* now means "Thank you;" again, it expresses joy. When moved by a feeling of dislike for an individual of his own race, or of jealousy of a rival, the animal spits and growls, thus giving utterance to threats and imprecations.

The number of mammals which can articulate syllables is small. Sheep utter no sound but that monotonous *ba*. Some gibbons of the island of Java, when they wish to inspire fear, cry out with fury *ra ra*. For most animals guttural sounds appear to be uttered with greatest ease. The dog, though highly gifted as regards memory, the sentiment of affection, and intelligence, has no language, but only cries; he barks. Short, sudden expirations of air through the glottis produce this well-known voice; yelping is only a modified form of barking, expressive of joy. Howling is the result of a lengthy expiration with great resonance in the pharynx; it expresses profound grief or pain. Dogs express their wants more frequently by movements of the body, by the play of the physiognomy, and by touching with the muzzle than by the voice. They appear to communicate admirably with one another when organizing an expedition; they inform one another of the presence of objects that gratify their appetite. We once saw in the midst of a meadow, far from any house, the flayed carcass of an ox, which had lain for several days absolutely abandoned. A lonely dog, drawn no doubt by the scent, came to get a meal, and went back to the village to tell his acquaintance of what he had discovered; in less than an hour the carcass was torn in pieces by the teeth of a great troop of dogs.

Opportunities of studying the language of animals in the state of freedom are unfrequent; all animals flee from man, and very wisely. In captivity, and cut off from their own kind, they become silent, or merely utter a few cries or murmurs. Were a human being to be held as a prisoner in a family of chimpanzees he would be reduced to the same extremity. Travelers have sometimes observed monkeys when well within range of sight and hearing; they have always observed that the different explosions of voice have each its own meaning, whenever it is designed to establish concert of action between individuals. The cercopitheci, the most graceful and sprightly monkeys of Africa, live together in more or less numerous groups. Having for their usual dwelling-places the branches of trees, they descend to the ground with great misgiving, and only in order to go foraging. On an expedition the band of cercopitheci march under the command of a chief, who is always an old male experienced in the ways of men and animals. At first the troop advance cautiously, passing along the highest branches of the trees. Now and then the chief climbs into one of the loftiest tree-tops and peers into space. If all is well, he makes announcement accordingly in guttural tones, and the troop show that they are reassured; if the chief suspects or perceives danger, he utters a peculiar cry, which is understood by all, and the troop retreat in confusion. The marauders, having reached the edge of the forest, descend to the ground. Then begins a hideous massacre of sorgho and maize. The sajous, those pretty little South American monkeys kept in every menagerie, also show the resources of the inarticulate voice as a means of communication among animals. One day the naturalist Rengger, while wandering along the border of a forest, observed a family of these monkeys whose conduct interested him. One individual, having parted company with the rest, had found an orange-tree loaded with ripe fruit. Without going to the trouble of turning about, he uttered a series of short cries, and made for the tree with the speed of an arrow. The others understood all, and in an instant were assembled amid the branches of the tree, enjoying the savory fruit. If man had no articulate speech, he would have no difficulty in constructing a language by the aid of sounds or cries diversified by intonation, intensity, and resonance, and variously combined. Such a language no doubt could never equal the languages of Homer, of Dante, of Shakespeare, and of Bossuet, but it would answer all the essential needs of life. By supposing such an imaginary though realizable mode of communication, we may form an idea of the more or less limited language of animals.

In mammals the sounds of the voice differ considerably with respect to volume, timbre, and pitch; these differences we can in some measure account for by peculiarities in the conformation of the larynx. In horned animals the vocal cords are lax, but little prominent, never coming near to one another, nor vibrating with much force. The sounds they produce are grave, as in the lowing of cattle. The rodents, as hares, rabbits, squirrels, and mice, whose vocal cords are thin, emit acute cries. Some species, belonging to different mammalian groups, have air-pouches opening into the larynx which produce extraordinary resonance. Some monkeys are distinguished for the enormous development of these pouches, and their voice is very loud. The howling monkeys, also called stentors, which inhabit the deepest forest recesses of the New World, can be heard, says Humboldt, at the distance of a kilometre and a half, and farther still according to other travelers. In the elephant the lateral cartilages of the larynx do not come into mutual contact, and the vocal cords, having an oblique direction, seem to be incapable of great tension; hence the voice of the elephant is deep, but at the same time very powerful. If we could observe in animals the play of the larynx during the emission of the voice, we should discover many curious and instructive actions of the glottis. But here we meet with an almost insuperable difficulty, for we can place but little reliance on the good-will of animals. Nevertheless, Mandl, trusting to his skill in the use of the laryngoscope, by no means despairs of success, knowing well that by dint of patience we often succeed in removing the most formidable obstacles. After man, birds hold the most prominent place among animate things in the concert of Nature; they enliven field, forest, and garden, with an infinity of chirrupings, leading one's thoughts to dwell on the pleasure of living. The structure and mechanism of the vocal apparatus of birds have been studied by many naturalists. George Cuvier discovered the precise point where the voice is formed. Birds have two larynges, one at the top of the trachea, and the other at the bottom. It is the latter alone which produces the sounds: the former acts only as a resonator. This is easily shown by experiment: if we cut the trachea in the middle, the voice remains. The vocal organ has the form of a box, to which anatomists give the name of drum. It is formed of the lowermost rings of the trachea and the uppermost rings of the bronchi. Commonly the larynx is divided in its inferior portion, sometimes by the angle of union of the bronchial tubes, again by a bony plate which serves as a point of attachment for a membrane rising from the inner margin of each of these tubes, and bounding the glottis with an opposing prominence, the edge of which is elastic. Thus two lips discharge the functions of vocal cords; they become tense or relaxed by the action of a muscular apparatus which in some cases is very simple, in others highly complex. The enormous variety which obtains in the vocal powers of birds necessitates a corresponding diversity in the details of the structure of the larynx and in the conformation of the trachea.

Parrots, being social in their nature, live in large flocks in the most favored climates of the globe; their habit of prattling is not impaired by captivity. When several individuals are together, they appear sometimes to engage in interminable conversations. On the alert for every voice-sound, and even for every noise, parrots imitate these with wonderful ease; thus they readily imitate the articulate speech of man, a phenomenon as yet unexplained. The movements of the tongue, no doubt, play an important part in the articulation of these sounds, but the nature of the resonances leads us to suspect a special activity of the superior larynx. The researches which have been undertaken into this matter will perhaps throw some light upon one of the most singular aptitudes possessed by animals. It is commonly supposed that parrots cannot attach any meaning to the phrases which they have learned; but this is not strictly exact. Occasionally individuals possessed of the advantages of great natural intelligence and good training employ words to make requests; they make proper reply to a question or to a sign. It might be supposed that parrots owe their power of speaking to the peculiar conformation of their tongue; but this is rendered doubtful by the performances of the magpie, the blackbird, and the starling. In these birds the tongue is thin, and yet they have no difficulty in pronouncing any articulate sound; this fact gives strength to the idea of the influence of the superior larynx. A starling, distinguished for its power of speaking, which at one time we had occasion to observe, very well knew the value of sundry words. He gave expression to his wants in good French, emphasizing his words with the flapping of his wings. This bird was very fond of the bath, and often called for water; on seeing a person taking hold of a pitcher the bird would exclaim, "Come quick, come quick!" with increasing force in case he was obliged to wait.

Most small birds have their call, their chirp of joy or of fright, their battle-cries: all these voice-explosions, containing as they do both vowel and consonant sounds, show how easy and natural articulation is to these animals. The species which possess the power of singing have a very complex vocal apparatus. The nightingale excels all the other songsters of the woods in power, clearness, and sweetness of tone. Her notes, whether joyous or plaintive, are always melodious. This bird acquires the power of song only after long practice. The young ones are usually very indifferent singers, and it is only those individuals which possess special gifts that give to the vocal art its highest expression. Among all the pretty feathered denizens of our woods, the males alone possess a fine voice; they utter their song in order to win mates who cannot compete in vocal talent. They are mute for a great part of the year, but, when the mating season approaches, their nervous action is quickened, and the blood is determined to the organs of voice.

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## WHAT ARE BATS?

By St. GEORGE MIVART, F.R.S.

THE group of animals called "Bats" is one full of interest to those specially occupied with the study of animal structure—the anatomist, the physiologist, and the philosophical zoölogist. At the same time it must be confessed that bats are far from exciting that general interest which in fact they merit. This disregard, however, is very natural. The small size of the bats inhabiting this and other parts of the temperate regions of the globe conspires with their nocturnal habits to remove them from general observation, while the great similarity one to another of their different species is an obstacle to their popularity even among zoölogists—since it makes their discrimination and classification a matter of difficulty.

Yet bats are, as I hope we shall see, really *very* interesting animals. The bat exhibits to us the body of a beast, specially modified to live the life of a bird, and at the same time serves to give us a fair conception of certain ancient reptilian forms, the remains of which are found deeply buried in deposits made untold ages ago—in the secondary rocks.

But what is a bat? Probably not one of my readers would be likely, if called upon to answer, to fall into the old error of considering it a kind of bird!

All who have ever examined a bat closely, and observed its fur, ears, and teeth, must, I think, have recognized it as a kind of beast. Its real affinities, however, serve excellently well to demonstrate how little mere external aspect can be trusted as a guide to fundamental relationship. The *bat* is essentially an animal of the air—all its structure is modified for flight, and it rarely *descends* to the surface of the ground. The *mole*, on the contrary, is essentially an animal of the earth—all its structure is modified for burrowing, and it rarely *ascends* to the surface of the ground. The contrast could hardly be more complete, and yet the bat and the mole are cousins—the mole, the hedgehog, and the shrew-mouse, belonging to a group of beasts with which the bats show no inconsiderable affinity.

I have spoken of the opinion that the bat is a kind of bird. This view seems to have been entertained by the Jews, and the "bird of darkness" is placed, in Deuteronomy xiv. 18, among the unclean ones forbidden as food:

"And the stork and the heron after her kind, and the lapwing and the bat."

Aristotle, though he placed the bats among flying animals, and therefore among birds, distinctly recognized the differences in their organization; and the same thing may be affirmed of Pliny. But in spite of this, and although Albertus Magnus, in the middle ages, was fully acquainted with the true nature of bats, as beasts, as well as with their winter torpidity, we find later on a retrogression of opinion.

Thus Belon, in 1557, in his "Histoire de la Nature des Oyseaux," includes bats with his birds. At the same time, he was not unacquainted with the mode of their reproduction.

Yet later—by nearly a century—in 1645, Aldrovandus decided that bats were rather birds than beasts, and this in spite of his careful study of them, as proved by his beginning to distinguish their different kinds one from another.

Some twenty-five years later, Ray gave them their true position among quadrupeds—a position which they have ever since retained.

The Teutonic mind seems early to have appreciated the true nature of bats, as we may judge from the German name, *Fledermaus* and the old English term, *flittermouse.*

Let us look a little closely at our subject of to-day—the bat.

In the first place, there is a little rounded body, covered with soft fur, which is indeed, what Shakespeare calls it, "wool," when giving the ingredients of the caldron of *Macbeth's* witches.

There is a small head, little eyes, large ears, a tail, and two pairs of limbs of very unequal size. The hind-pair (the legs) are of moderate length and singularly disposed, so that the knees are turned almost backward, like our elbows.

Each leg terminates in a foot, furnished with five toes, each with a long, curved claw, all of about the same length. These toes are not webbed, like those of a duck, but are free.

The other pair of limbs (the arms and hands) are of exceeding length. Both the arm and forearm are long—especially the latter—but it is the fingers which are so wonderfully drawn out, and they *are* webbed, like the toes of a water-fowl. Moreover, the web not only connects these long fingers together, but also connects them with the sides of the body and with the legs (as far as the ankle); and does not stop even here, but continues on to the tail, thus connecting it with the two legs.

This large web or membranous expansion has two names. The part belonging to the hand and joining the sides of the body (which is supported by the fingers as an umbrella by its rods) is termed the *alar membrane.* The part connecting the legs with the tail is called the *interfemoral membrane.*

Looking more closely, however, we find that, though the four fingers of each hand are thus bound together, the thumb is free, standing out at a wide angle, and furnished with a very long and strong hooked claw. Of the four fingers, it is only the first which is clawed.

The uses made by the bat of its singularly-formed limbs are, of course, in exact correspondence with their structure. The fore-limbs are true organs of flight; the hind-limbs and tail have a rudder-like action. Besides flight (their predominant mode of motion), bats can crawl upon the surface of the earth with an awkward, shuffling gait. When so crawling, the wings are closed (the long fingers then lying side by side), and the animal rests on its wrists and hind-feet, the body being dragged forward by the help of the strong, hooked thumb-nails, which also help it to climb with ease up any rough surface, even though perpendicular.

When at rest, bats usually hang suspended, head downward, by the claws of their feet, though occasionally they turn round and hang from the claws of their thumbs.

Most nocturnal beasts have large eyes, but most bats have very small ones.

This is perhaps due to the fact that bats in their flight are guided by an extraordinarily delicate sense of touch—so delicate as to seem almost like a sixth sense.

The external ear of most bats appears at first to be double—a very small one seeming to stand up inside the larger one. This appearance, however, is due merely to the very large development of a little piece which in ourselves projects backward as a small rounded process guarding externally the opening of our ear, and called the *tragus*.

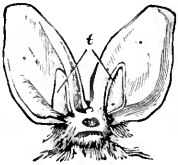

FIG. 1.—HEAD OF LARGE-EARED BAT. *t*, Tragus.

The food of our English bats consists of insects, and their teeth bristle with sharp points, well suited to pierce the chitinous cases by which the bodies of insects are protected.

The stomach (like that of most beasts which live upon a purely animal diet) is a simple, short, and rounded bag.

The female is provided with a pair of milk-glands, situated on the breast—as in the apes and in man.

The skeleton of the bat, when compared with those of some other animals, affords an excellent example of how fundamental uniformity of structure may underlie forms which are strikingly different—in accordance with diverging habits of life.

I have already called attention to the divergent aspects of the aërial bat and the subterranean mole. Yet the bones of the flying-organ of the bat closely resemble those of the burrowing organ of the mole, save as regards the relative shapes and dimensions of the component bones. But, while in the bat these bones are drawn out into excessive length and tenuity, in the mole they exhibit the maximum of concentration and robustness. Now, both these conditions are but diverging manifestations of the human structure, and the same indeed may be said of such extreme modifications as the fore-leg of the horse or the paddle of the whale.

But the bat and the mole present us with a special point of similarity in their skeleton not found in the other animals named, including ourselves.

It is that the breastbone in both the bat and mole develops a median ridge or keel. This keel serves to afford additional surface for the attachment of powerful muscles which pass thence to the arms, and which, in the bat, by their contraction, strike the wings downward in flight.

Every one present must have observed, when carving a fowl, that there is a ridge or keel to the breastbone, and that a voluminous mass of muscle—the breast of the fowl—is situated on each side of such keel. Now, our bat has not got such a mass of muscle on each side of the keel of its breastbone as has the bird, and for a very good reason. In the bat, as in ourselves, the muscles which antagonize those just noticed (and which draw the arms away from the breast) are situated in the back; but, in the bird, both the muscles which strike the wings downward, and those which raise them upward, are together placed upon the breast, and hence its much deeper and more conspicuous keel. Still, though the muscular structure of the breast of a bat is not so perfectly arranged for flight as is that of a bird, it is an approximation to bird-structure, and one we can well understand from the similarity of action. But it may puzzle some of my hearers at first to think why the mole, of all creatures in the world, should have a breastbone at all like that of a bird. But a moment's reflection will make it obvious that the mole also requires most powerful breast-muscles, in order that it may dig its way through the soil with the wonderful speed with which it does dig through it. Similar causes produce similar effects, and thus it is that the mole, like the bat and the bird, comes to have a keeled breastbone.

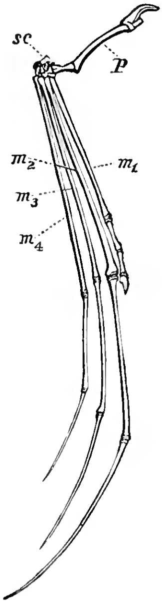

Fig. 2.—*s c*, wrist-bones; *p*, bones of thumb; $m_{1-4}$, bones of middle part of hands.

The membrane of the bat's wing is a structure of extreme and peculiar delicacy as regards the sense of touch, and the perfection of this sense is doubtless contributed to by a special condition of its blood-vessels. Although the sense of touch depends, of course, directly on the nerves, the functional activity of the nerves depends upon the quantity and the sufficiently rapid renewal of the blood sent to them. This is shown by the familiar examples of numbness brought about by checking the supply of blood to any part with a ligature, as also by the increased sensibility occasioned by inflammation; that is, through a more copious supply of blood. Now, in most animals, as in ourselves, the heart pulsates with rhythmical contractility; but the blood-vessels which distribute the blood over the body are not themselves contractile, however highly elastic they may be. In the bat's wing, however, the vessels which convey blood toward the heart (i. e., the veins) have been found by Dr. Wharton Jones to be themselves positively contractile, and so fitted in a most exceptional manner to help on the blood-supply, thus indirectly augmenting the power of touch.

This exceptional condition of the vascular system may, then, have something to do with that exceptional perfection of the power of sensation before referred to, and which was experimentally demonstrated by Spallanzani. He found, not having the fear of anti-vivisectionists before his eyes, that bats deprived of sight, and as far as possible also of smell and hearing, were still able not only to avoid ordinary obstacles to their flight in strange localities, but even to pass between threads purposely extended in various directions across the room in which the experiments were made. This skill it is believed is due to an excessively delicate power of sensation possessed by the flying membrane—a power enabling the creatures by atmospheric pressure and vibration to feel, before contact, the nearness of adjacent objects. Dr. Dobson, who has paid more attention to bats, perhaps, than any other living naturalist, is disposed to think, and very reasonably so, that tactile power may be thus greatly increased by such increase of the surface on which tactile sensations may be received as is found in the bat's wing, and that this is the explanation of the mysterious power revealed to us by Spallanzani.

The flight of the bat compared with that of most birds is excessively fluttering; but it is a true and perfect flight, and therefore very different from the analogous action of other beasts called "flying," such as the flying-squirrels, the flying-opossums, and the flying-lemur. In these animals the skin of the flanks can indeed be extended outward to the arm and the leg, and when so stretched (as when these animals take long jumps) seems as a sort of parachute to sustain them somewhat in the air, and so far break their fall as to enable them to flit from one bough to another; but they cannot truly fly. The flying-lemur is the best furnished in this respect, as it has not only a very extensive "alar membrane," but a short expansion of skin connects together not only the fingers but the toes also (which is not the case in bats), and has a true interfemoral membrane extending from the hind-legs to the tail.

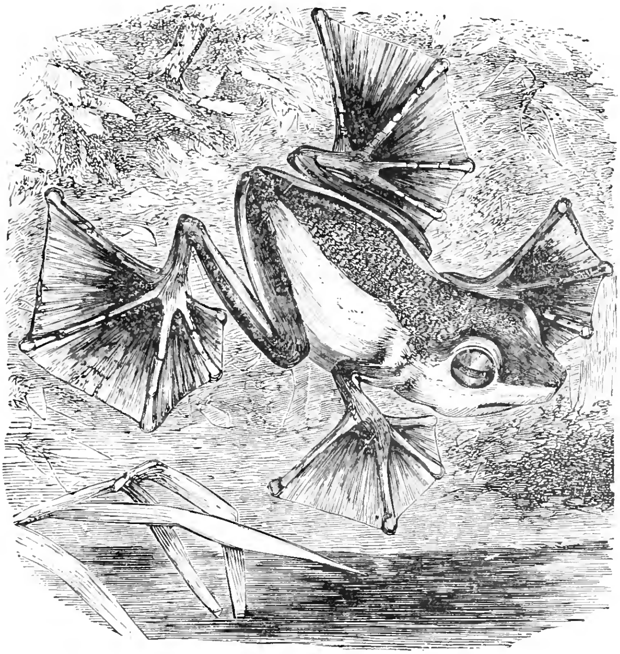

FIG. 3.—A FLYING FROG.

There is no other such instance in beasts, or in any existing reptiles; but web-footedness is carried to such an extreme degree in a certain frog found in Borneo as to give rise to the conjecture that it was a flying animal.

Mr. Wallace, in his travels in the Malay Archipelago, encountered in Borneo a tree-frog (*Rhacophorus*), to which he considered that the term "flying" might be applied. He tells us:

"One of the most curious and interesting creatures which I met with in Borneo was a large tree-frog, which was brought me by one of the Chinese workmen. He assured me that he had seen it come down in a slanting direction from a high tree as if it flew. On examining it I found the toes very long and fully webbed to their extremity, so that, when expanded, they offered a surface much larger than the body. The fore-legs were also bordered by a membrane, and the body was capable of considerable inflation. The back and limbs were of a very deep, shining, green color, the under surface of the inner toes yellow, while the webs were black rayed with yellow. The body was about four inches long, while the webs of each hind-foot, when fully expanded, covered a surface of four square inches, and the webs of all the feet together about twelve square inches. As the extremities of the toes have dilated disks for adhesion, showing the creature to be a true tree-frog, it is difficult to imagine that this immense membrane of the toes can be for the purpose of swimming only, and the account of the Chinaman that it flew down from the tree becomes more credible."

Although no existing reptile is thus furnished, there is a small Asiatic lizard which is ordinarily spoken of as "flying," the *Draco volans*. And, in fact, though this creature cannot truly fly, but only flit, it has a membrane which can be extended from each side of the body, and which, like the bat's wing, is supported by a number of bony rods. These rods, however, are not, as in the bat, enormously elongated fingers, but are elongated ribs, which stand out freely from the body when jumping, but otherwise are folded back against the flanks.

Existing reptiles, then, present us with no close resemblance to bat-structure; but when we come to extinct reptiles—reptiles which flourished during and anterior to the deposition of our chalk-cliffs—the secondary or mesozoic period—we there find reptiles to have existed which present the most striking analogies with existing bats in all that regards their modes of locomotion, and their structure as far as it is related to such modes of locomotion.

These reptiles flew in the same way that bats do, by means of a vast membrane extending from each enormously-elongated hand to the adjacent side of the body.

While, however, in the bat all the fingers of each hand are enormously elongated (to support the alar membrane)—the thumb alone remaining free—in these flying reptiles only a single finger of each hand was thus elongated, the others remaining short, and being provided with claws like the thumb.

With the approach of the winter season bats (like dormice) fall into a peculiar state of winter sleep called hibernation. For this purpose they generally assemble together in large numbers, in out-of-the-way places, caverns, hollow trees, or the roofs of buildings, hanging head downward by the claws of their feet. During this condition the most important functions of life—breathing and the circulation of the blood—are performed only with exceedingly-reduced activity, the temperature of the body becoming notably diminished.

Some of our English bats may be kept in confinement and partly domesticated for a time, small pieces of raw meat being given to them in lieu of their natural insect-food. Speaking of the long-eared bat, Mr. Bell tells us:

> "It is more readily tamed than any other, and may soon be brought to exhibit a considerable degree of familiarity with those who feed and caress it. I have frequently watched them when in confinement, and have observed them to be bold and familiar even from the first. They are very cleanly; not only cleaning themselves after feeding, and at other times, with great assiduity, but occasionally assisting each other in this office. They are very playful, too, and their gambols are not the less amusing from their awkwardness. They run over

and against each other, pretending to bite, but never harming their companions of the same species; though I have seen them exhibit a sad spirit of persecution to an unfortunate Barbastelle which was placed in the same cage with them. They may be readily brought to eat from the hand, and my friend Mr. James Sowerby had one which, when at liberty in the parlor, would fly to the hand of any of the young people who held up a fly toward it, and, pitching on the hand, take the fly without hesitation. If the insect were held between the lips, the bat would then settle on its young patron's cheek, and take the fly with great gentleness from the mouth; and so far was this familiarity carried that, when either of my young friends made a humming noise with the mouth in imitation of an insect, the bat would search about the lips for the promised dainty."

One of the "young friends" here referred to is now the esteemed secretary at the Botanical Gardens, and he has assured me of the truth of the anecdote.

The cry of the bat is exceedingly shrill, so much so that some persons' ears are quite unable to detect it.

Homer compares the voices of the ghosts to the cries of bats. In the twenty-fourth book of the "Odyssey," 6, he says: "As when bats in a corner of a great cave, when one of them has fallen from off the cluster—so they (the ghosts) went along screaming."

Or, as Pope gives it:

'Trembling the spectres glide, and plaintive vent
Their hollow screams along the deep descent,
As in the cavern of some rifted den,
Where flock nocturnal bats, and birds obscene;
Clustered they hang, till at some sudden shock
They move, and murmurs run through all the rock.
So cowering fled the sable heap of ghosts."

Bats bring forth but one or two young ones at a birth—when they are received into the interfemoral membrane as into a cradle—the mother then hanging suspended not by her feet but by her thumbs.

The young are born naked and blind, and are suckled at the breast much as is the human infant.

There are many kinds of bats, though their number is uncertain.

There *are* some fourteen species even in England, and at least three hundred and twenty, arranged in some seventy-nine genera, in the world at large.

One of our English bats, already referred to as "the long-eared bat," does indeed merit its name, since it has relatively the largest ears found in the whole animal kingdom, being about equal to the length of its entire body. They are capable of being folded up, and generally are so folded, during sleep.

Another kind of bat found in England is called the leaf-nosed bat, because in it not the ear but the nose is the seat of extraordinary skin-development—productions of skin curiously folded surrounding and surmounting the external nostrils.

The use of this membrane, according to Dr. Dobson, is to serve as a tactile organ (like the wings); and this is the more probable, seeing that that family of leaf-nosed bats which is represented in England have the smallest eyes, and are devoid of a tragus or inner part of the seemingly double ear before spoken of.

Bats are divisible into two great groups. One of them includes all the insect-eating bats (with or without nose-leaves), more or less like the bats which inhabit this country. They have almost always teeth such as those already described, often a very large tragus to the ear, and a stomach short and rounded, or at least not prolonged at its pyloric (or more specially digestive) extremity.

Fig. 4.—British Bats.

These bats are subdivided into various families, three of which alone immediately concern us: 1. The *Vespertilionidæ*, which includes, among very many others, all the English bats without a nose-leaf; 2. The *Rhinolophidæ*, which includes, among very many others, the English leaf-nosed bats; and 3. The *Phyllostomidæ*, or leaf-nosed bats of America.

The other group of bats are made up of those, mostly of large size, called *flying-foxes*, of which we have specimens now living in the Zoölogical Gardens. They are confined to the tropical and sub-tropical regions of the Old World and the Pacific, but are not found even in the hottest regions of South America. They have grinding teeth, which are not drawn out into sharp points, but have their crowns marked simply with a longitudinal furrow, in accordance with their fruit-eating habits, and their stomach (also in accordance with this habit) is much prolonged at its pyloric, or more specially digestive, end.

Certain leaf-nosed bats of South America go by the formidable name of vampires, from their reputed blood-sucking habits.

Although such a habit could only have been attributed erroneously to the entire group, one certain kind of this group is very truly blood-sucking, and its organization is peculiarly and very strikingly modified to efficiently subserve this function.

The bat in question is called *Desmodus*, and the truth as to its blood-sucking habit has been fully established by the testimony of Mr. Darwin.[1] He tells us: "The vampire-bat is often the cause of much trouble, by biting the horses on their withers. The injury is generally not so much owing to the loss of blood as to the inflammation which the pressure of the saddle afterward produces. The whole circumstance having been lately doubted in England, I was therefore fortunate in being present when one (*Desmodus d' Orbignyi*) was actually caught on a horse's back. We were bivouacking late one evening near Coquimbo in Chili, when my servant, noticing that one of the horses was very restive, went to see what was the matter, and, fancying he could distinguish something, suddenly put his hand on the beast's withers, and secured the vampire. In the morning the spot where the bite had been inflicted was easily distinguished from being swollen and bloody. The third day afterward we rode the horse, without any ill effects."

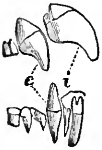

FIG. 5.—TEETH OF THE VAMPIRE BAT (*Desmodus*). *i*, cutting-teeth; *c*, eye-teeth.

The special modifications of structure which harmonize with this

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[1] "Journal of Voyage of Beagle," vol. i., p. 22.

special function are mainly two: First, the form of the teeth; and, secondly, that of the stomach.

As to the teeth, the grinding ones are reduced to a minimum both as to size and number; while the two middle or cutting teeth of the upper jaw are of great size, with a sharp cutting edge well fitted to inflict the small incision needful for the animal's nourishment.

As to the stomach, it presents us with a structure unique in the animal kingdom. Here it is not the pyloric end of the stomach, but the opposite or cardiac end, which is produced into an enormously long pouch, while the opposite or pyloric end is reduced to a mere rudiment—the highly-nutritious food (blood) requiring very little digestion, but needing a capacious chamber for its speedy reception.

Although this is the only bat perfectly organized to live by blood-sucking exclusively, nevertheless it is probable that various other kinds practise blood-sucking as at least one part of their mode of nutrition.

The late distinguished zoölogist belonging to the Zoölogical Society, Mr. Blyth, has observed this habit in a leaf-nosed bat of India, one belonging to quite another family than that to which the American vampire belongs. The bat in question is called *Megaderma Lyra.* Respecting its habits Mr. Blyth tells us[1] as follows:

> "Chancing one evening to see a rather large bat enter an out-house from which there was no other egress than by the doorway, I was fortunate in being able to procure a light, and thus proceed to the capture of the animal. Upon finding itself pursued, it took three or four turns round the apartment, when down dropped what at the moment I supposed to be its young, and which I deposited in my handkerchief. After a somewhat tedious chase, I then secured the object of my pursuit, which proved to be a fine pregnant female of *Megaderma Lyra.*
>
> "I then looked at the other bat which I had picked up, and, to my surprise, found it to be a small *Vespertilio*, nearly allied to the European *V. pipistrellus*, which is exceedingly abundant, not only here, but apparently throughout India, being the same also, to all appearance, as a small species which my friend Dr. Cantor procured in Chusan. The individual now referred to was feeble from loss of blood, which it was evident the *Megaderma* had been sucking from a large and still bleeding wound under and behind the ear; and the very obviously suctorial form of the mouth of the vampire was of itself sufficient to hint the strong probability of such being the case. During the very short time that elapsed before I entered the out-house, it did not appear that the depredator had once alighted: but I am satisfied that it sucked the vital current from its victim as it flow, having probably seized it on the wing, and that it was seeking a quiet nook where it might devour the body at leisure. I kept both animals wrapped separately in my handkerchief till the next morning, when, procuring a convenient cage, I first put in the *Megaderma*, and, after observing it some time, I placed the other bat with it. No sooner was the latter perceived than the other fastened on it with the ferocity of a tiger, again seizing it behind the ear, and

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[1] In the "Journal of the Asiatic Society of Calcutta," vol. xi., p. 225, quoted in P. Z. S., 1872, p. 713.

made several efforts to fly off with it; but, finding it must needs stay within the precincts of the cage, it soon hung by the hind-legs to one side of its prison, and, after sucking its victim till no more blood was left, commenced devouring it, and soon left nothing but the head and some portions of the limbs. The voidings observed very shortly afterward in its cage resembled clotted blood, which will explain the statement of Stedman and others concerning masses of congealed blood being always observed near a patient who has been attacked by a South African vampire. Such, then, is the mode of subsistence of the *Megaderma*."

Bats are most widely diffused over the surface of the globe, as their powers of flight might lead us to expect. Even Australia—so very peculiar in the character of the other beasts which inhabit it—possesses bats belonging to both of the bat families which are found in our own island.

But, although the whole group of bats, and also that family to which most English bats belong—the *Vespertilionidæ*—are thus widely distributed, the geographical limits of some families of bats are very sharply defined.

To appreciate these facts it is necessary to be acquainted with the geographical areas into which the surface of our globe may be divided, each considerable tract of the earth's surface having its more or less peculiar animal population, or *fauna*, as it has its indigenous plants, that is, its *flora*. The earth's surface is divisible into six zoölogical regions:

1. The *Palæarctic region*, or Europe, Asia north of the Himalayas, and Africa north of the Sahara.
2. The *Ethiopian region*, or Africa south of the Sahara, and including Madagascar and also Arabia, which, geologically, is part of Africa.
3. The *Oriental region*, or Asia south of the Himalayas, with Southern China and the Philippine Islands and Indian Archipelago as far as the island of Bali.
4. The *Australian region*, or Australia, New Zealand, the less remote Pacific Islands, and those of the Indian Archipelago from New Guinea up to Lombok.
5. The *Neotropical region*, or South America, together with tropical North America and the West Indies.
6. The *Nearctic region*, or temperate North America and Greenland.

Now, the whole group of flying-foxes is strictly confined to the tropical regions of the Old World and Australia. In the same way the family of leaf-nosed bats, like those of England—the *Rhinolophidæ*—is limited to the Old World, though reaching there much higher latitudes than do the flying-foxes.

The group to which the vampires belong—the *Phyllostomidæ*—is strictly confined to the Neotropical and Nearctic regions; and the

Neotropical region is not only distinguished as the headquarters of the *Phyllostomidæ*, but also by being altogether destitute of the flying-foxes and *Rhinolophidæ*.

Such being the relation of bats to space—their geographical distribution—what are their relations to time—their geological distribution?

I assume that my readers are acquainted with the fundamental facts and laws of geology, and know that the successive layers, of which the superficial crust of the earth is in very various degrees composed, are classifiable into three sets: 1. The Primary or Palæozoic rocks; 2. The Secondary or Mesozoic rocks (from the Trias to the Chalk inclusively); and, lastly, 3. The Tertiary or Cainozoic rocks, extending upward from the Chalk to the present day.

Fig. 6.—Flying-Fox (*Pteropus Whitmeei*).

Remains of beasts more or less closely resembling some of those existing now in Australia are found low down in the secondary rocks, namely, in the Triassic and Oolitic formations. Generally speaking, however, beasts such as those which now exist are not found deeper than the Tertiary strata, and this is the case with bats.

The oldest fossil bat yet known is represented by a few teeth found in Eocene deposits in Suffolk. The oldest perfect fossil bat is the *Vespertilio Parisiensis* of the gypsum-bed of Montmartre, near Paris.

Some forms of existing beasts, however, which are *now* distinct enough, such as the ox and the pig, or the tapir and the horse, were preceded in early Tertiary times by others which were more or less intermediate in structure. This is not the case as regards bats. Bats, as soon as they appear at all, appear as thoroughly and as perfectly organized bats as are those living among us now.

This leads us to speculate upon questions of origin; but, before so doing, let us see that we have a clear idea of what a bat is, and can give a good definition of it.

In order that we may have this clear idea, we must consider for a few moments zoölogical classification.

The whole group of animals is fancifully termed the animal kingdom, in contradistinction to the world of plants—the vegetable kingdom.

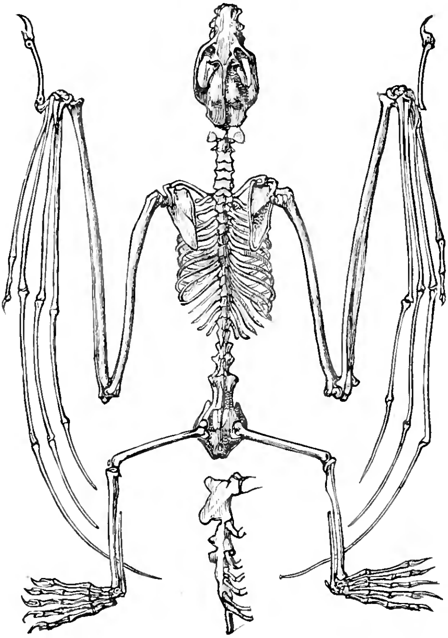


FIG. 7.—SKELETON OF FLYING-FOX. SIDE-VIEW OF STERNUM.

This vast mass of animals is subdivided into a number of very large groups, each of which is a called a sub-kingdom. Thus, we have the sub-kingdom to which we ourselves belong—the vertebrate sub-kingdom; the sub-kingdom of insects, etc.; that of snails, cuttle-fishes, etc., and so on.

Each of these various sub-kingdoms is again divided into certain subordinate, but still very large groups, each of which is called a class.

Thus, the sub-kingdom Vertebrata is made up of the class of man and beasts, that of birds, that of reptiles, that of frogs, toads, and efts, and that of fishes.

Every class is again subdivided into certain subordinate groups, termed orders.

Each order is composed of families, each family of genera, and each genus of its component kinds or "species."

Now, the bat, as already said, belongs to man's own class, possessing as it does all the characters which distinguish that class from the other classes of vertebrate animals.

Man's own class, Mammalia, is divisible into some dozen orders, and all the bats form one such order (*Cheiroptera*), into which no animal but a bat is admitted. The characters of this order are the possession of a truly flying membrane, sustained by very elongated fingers; and the bat is capable of being very shortly defined, namely, as *a truly flying mammal.*

Bats present no real resemblance whatever to birds, but are, of course, much more like ourselves (who are their class-fellows) than they are like any bird.

Similarly, in spite of this analogical relation of bats to those extinct reptiles, the pterodactyls, these creatures have no true affinity. Pterodactyls are aërial modifications of the Reptilian type, just as bats are aërial modifications of the Mammalian type. We may say, in a rough and general way, as pterodactyls are to reptiles, so are bats to mammals.

Before concluding we may now glance at the question of the genesis or origin of bats. To those who accept the doctrine of Evolution —as I myself do—there can be no question but that bats did arise by natural generation from some anterior beasts which were not bats. But at what period and from what progenitors? these are questions which it is quite impossible to answer at present. As has been said, there are certain cases in which we may imagine now existing more highly specialized and differentiated forms were developed from anterior less highly specialized and differentiated ones. We may do so, e. g., as regards the horse and the ox. But we cannot do so as regards the bat, because up to the present time no fossil remains whatever have been found which connect bats with other creatures. Moreover, the development of the bat's wing, difficult as it is to conceive upon any view of evolution, seems to me to be especially difficult as the mere result of the survival of the fittest, when we consider the origin of the initial stages of the organ. The nearest existing relatives of the bats which are not bats are perhaps the little shrew-mice belonging to the order Insectivora. Some of these are aquatic; and it is conceivable, though there is no fragment of evidence in favor of it, that some ancestral aquatic form may have developed long fingers and webs like those of the flying-frog. This speculation does not, however, commend itself to my mind as a satisfactory one; and though, doubtless, could we see all the extinct forms of life which have existed during the secondary period, we should find some creatures developing by more or less rapid stages along a definite course in the direction of the type of structure selected for our consideration to-day, and, though I am ready to make an act of scientific faith in the existence of such creatures, I confess my imagination fairly baffled in its attempts to depict them, or the road which this particular course of evolution followed. We must wait patiently for more light from paleontology. But we may wait very hopefully. We may do so because the wonderfully rich harvest of fossil remains now being gathered in North America supplies us with good and solid ground for hope.

Already forms have been discovered there so strange that they cannot be satisfactorily grouped in any existing order of mammals—forms such as imagination could hardly have anticipated. We may, then, not unreasonably expect that sooner or later—perhaps very soon—fossils deeply buried in the secondary rocks will come to light, clearly pointing out the line which has been followed in the evolution and development of the only truly flying mammal—the bat.—*Popular Science Review.*

## ON THE FORMATION OF LAKES.

By I. C. RUSSELL.

IT was not until the studies of Agassiz, Forbes, and others, among the Alps of Switzerland, had made us acquainted with the character and action of glaciers, that we could at all understand many of the most curious and interesting features connected with the formation of the multitude of lakes with which we are more or less familiar, and which lend so much beauty and grandeur to the scenery of the world.

As some classification is necessary for the understanding of a series of facts, we will arrange lakes under four heads: 1. Those filling glacier-worn rock-basins; 2. Those confined by banks of sand, gravel, bowlders, etc., or, in one word, by moraines; 3. Those formed by a subsidence of their bottoms, or by the elevation of the country surrounding them, commonly by the secular changes of level to which the crust of our globe is subject; 4. Lakes filling basins formed by volcanic action.

1. Lakes which fill rock-basins are such as are confined on all sides by the common rock of the country, so that in some cases a person can walk entirely around them without stepping off the solid rock; and in all cases they would be found to have a rocky rim inclosing them, were the superficial material removed. How such spoon-shaped depressions could be scooped out, was for a long time an enigma which eluded the search of the most painstaking observers.

As facts accumulated, however, it was noticed that the sides and bottoms of such lakes are smoothed, in many cases polished, and almost always covered with grooves and scratches; and also that in their vicinity beds of clay are usually found, intermixed with pebbles and large bowlders which, like the rocky basins, are also smoothed and frequently scratched. It was noticed, too, that the rock from which these bowlders and pebbles had been formed commonly differed from the rocks in place on the shores of the lakes. Thus, throughout New York and Ohio, huge bowlders are common, composed of crystalline rock found in place nowhere nearer than the Canadian Highlands, a hundred miles to the northward; while the peculiar native copper of Northern Michigan is sometimes found mingled with the bowlders and striated stones of the drift far southward in Ohio.

The problem now was to discover what forces in Nature could *polish* and *scratch* both rock-surfaces and detached stones, and could also transport masses of rock, tons in weight, far from their native home.

It is well known that the loose stones and pebbles along the seashore are made very smooth and round, and often polished, by the action of the waves. It might be thought from this that the pebbles found on the shores of the lakes, and imbedded in the clays, were fashioned in the same manner. On one occasion, at the Cape of Good Hope, the writer, after wandering for a time along the sloping sandy beach of Table Bay, came suddenly to a little rocky cove exposed to the full swell of the South Atlantic. As each wave broke on the steep, rocky beach and retreated, it was followed by a sharp, rattling sound that could be distinctly heard above the roar of the waves; we noticed, too, that the stones all along the shore were in motion, rolling down the beach, only to be caught up by the next white-capped wave that came in from the ocean, and again carried up the beach, and rolled and pounded against each other by the untiring waters, that were fast reducing them to sand and dust. On examining these water-worn stones, we found them all smoothed and rounded, and often beautifully polished; but in no case could we discover, even with a magnifying-glass, any that were scratched, or in any way marked similarly to the stones which we have so often examined in the clays and hard-pans that cover so great a portion of our Northern States. From this fact, and also from watching the action of the waves on many other coasts, we conclude that the sea tends to smooth and wear away the stones and rocks along its shores, but has no power to cover them with grooves and scratches; and that, instead of wearing the coast into pockets and basins, it tends only to grind down the islands and continents to one uniform level.

Again, we have traversed the deep, picturesque valleys of the southern Alps, where we could see the glaciers glittering on the mountain-sides far up at the head of the valley, and have noticed as we advanced that the rocks became more and more worn and rounded; that in sheltered places, along the sides of the valley, beds of thick plastic clay were to be found; and also that the whole valley was strewed with smoothed and rounded pebbles, together with huge bowlders, many of which were a hundred tons in weight. These were often planed off and grooved, precisely like many of the transported stones that are scattered so plentifully over the hills and valleys of the State of New York; and like them, too, frequently differed in the nature of their material from the rocks of the surrounding cliffs. As we ascended the valley, these peculiarities became more and more strongly marked; while around us the hills and knolls had a rounded and flowing outline, and formed what are known as *roches moutonnées*, the mountain-peaks that towered above were sharp and angular, and stood out against the clear sky like cathedral-spires.

All these facts have such a marked and intimate connection with the glaciers that still linger on the mountain-side, that no one—who had traversed those valleys, or traced the streams up to the ice-caves, from which many of them spring, turbid and overloaded with silt, at the foot of the glaciers—could doubt that these valleys, with all their peculiar features, owe their existence to the great extension of the glaciers, which in past time flowed from the mountains in great rivers of ice, and carved out those grand valleys to a depth of many thousands of feet in the solid rock. As these ancient glaciers retreated and melted away, they left the indisputable records of their presence throughout the valley.

The same connection of rounded and striated bowlders (called *Fündlinge*—wandering children—by the German peasants) with existing glaciers has been observed by Agassiz and others in the Alps of Switzerland. Not only these facts, but the manner in which the glaciers flow down the valleys like great rivers of ice, has been closely observed and measured; they have been seen time and again transporting immense amounts of dirt and stones on their surface, which in time formed part of the terminal moraines at their extremity. The sides and bottoms of the valleys through which they flow are smoothed and covered with scratches made by the pebbles and stones set in the bottom and sides of the glacier, which in their turn were rounded and scratched, often in various directions, caused by their breaking from their matrix, and being reset in a new position.

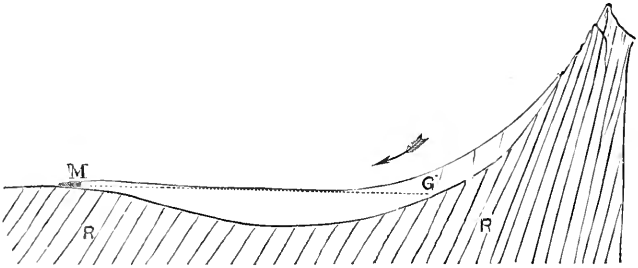
If we were to place the rounded and scratched stones from the drift ("hard-pan," "hog's-backs," etc.) of New York beside the similar stones broken from their icy fastenings in the bottom of the glacier of Zermatt, we should find them so similar in their markings that no eye could distinguish but that they had made the journey under the glacier side by side.

If we compare the smoothed and striated rocks from the bottoms and shores of Lake Erie, Cayuga Lake, or almost any of our lakes which fill rock-basins, with the rock-surface fresh from under the ice of the Mer de Glace, we shall find them wonderfully similar in their markings. The characters that are engraved upon them are the same.

Not only do we find these markings in connection with the present glaciers, but we find also the rock-basins themselves with the glaciers yet occupying their upper portions, and still at work grinding down the rocks. The best example of this kind, perhaps, in the world, is Lake Wakatipu, in New Zealand, which has a length of seventy miles, and a depth of 1,400 feet. This lake fills a true rock-basin, and bears every indication of having been excavated by the glaciers, which in the past were greatly extended, and have now retreated to the extreme upper end of the valley, while it has no connection with synclinal folds or volcanic fractures.

How can we resist the conclusion, then, that these bowlders, these beds of clay full of smoothed and striated pebbles, and these rock-basins with their sides covered with inscriptions—which we can now read with ease and accuracy if we take the records made by existing glaciers, as the Rosetta Stone—are all the work of glaciers, since the same results are produced at the present day by the action of ice, and by no other agency known?

A clearer idea of the manner in which a flowing glacier wears out a rock-basin can be gathered, perhaps, from the accompanying diagram, where the rock *R R* is shown, over which passes the glacier *G*, which wears its bottom less at the lower end, not only for the reason that the ice is continually wasting away, and growing thinner in the lower portion, but also because the material carried down on the surface of the glacier is deposited at its extremity *M*, in the form of a terminal moraine, and thus protects the rock beneath from further waste. When the ice of the glacier is melted away, and the terminus retreats up the valley, the basin which it leaves behind it becomes filled with water (from *M* to *G*), and thus forms a lake, which may be a mere pool across which a school-boy can skip a stone, a great inland sea like Lake Erie or Lake Ontario, or a mirror of grandeur like Lake Geneva or Lucerne, in Switzerland, and Lake Wakatipu and Lake Wanaka, in New Zealand.



It may be urged that these beds of clay, with their striated stones and huge bowlders, are found over a large section of our country, and are not confined to the region of the lakes. This is very true; and from it we conclude that where now so many happy homes are scattered, from Maine to the far West, the snows and frozen mists of a great winter once accumulated to many thousand feet in thickness, and formed a great glacier, like that which covers the interior of Greenland at the present day, which flowed southward, grinding down the country and acting as a ploughshare to prepare the land for a new harvest. Gradually this great winter began to pass away, and the spring-time in which we now live, to draw near. As the great glacier retreated northward, it left the country covered with beds of bowlder-clay and strewed with huge erratics from northern regions, which together with other *débris* form the surface material of all our northern country, where it has not since been swept away or covered by other and more recent deposits. It is often well exposed along our lines of railroads, and may be known at a glance by the great number of worn and rounded stones of all sizes that are scattered promiscuously through it. These evidences of glacial action are found as far southward as Cincinnati and the central portion of New Jersey, showing that here was the border of the icy mantle that was spread over all the northern regions. After this great continental glacier passed away, or had retreated far northward, smaller and detached streams of ice still flowed southward to complete the task of moulding the valleys and lake-basins. It is to these smaller glaciers that we attribute the formation of the multitude of lakes filling rock-basins that are scattered through the northern part of the United States and over the whole of the British possessions, many of which have been hollowed out in nearly horizontal beds of rock in the same manner as lake-basins are now forming under existing glaciers. Nor are the lakes which fill glacier-worn rock-basins confined to our own continent, but they form the most common and grandest lakes of temperate latitudes, which might be called the lake latitudes, so completely are the lakes of the world confined to these regions.

The theory of the glacial origin of certain lakes was first proposed by the distinguished English geologist, Prof. Ramsay, and, after being tested in nearly every glaciated region in the world, is now held, by those best qualified to understand it, as the simple and true history of the formation of many of our lakes.

2. The lakes of our second class, those which are confined by banks of gravel, bowlders, etc., owe their origin, like the ones we have been considering, to the action of ice. Lakes of this class are most commonly found in the deep Alpine valleys of mountainous regions, where the material which accumulated on the surface of the glaciers that once flowed through them, in the form of lateral and medial moraines, was carried down and deposited at the extremity of the

glacier in what is known as a terminal moraine, which in many cases stretched completely across the valley and marks the place where the terminal face of the glacier was stationary for a considerable period of time before it melted away, and allowed the water to accumulate in the space once filled by the ice. These glacier-built dams are to be met with in all countries which have been subjected to glacial action, and are especially well marked amid the Alps and in Scotland, where they have been most thoroughly studied, on the Scandinavian peninsula, in the Northern States of the Union, and amid the southern Alps of New Zealand. As the bottom of the valley in which such a lake is formed is usually worn deeper by the action of the glacier during the formation of the terminal moraine, this second form of lake-basin is quite often combined with the first.

To this second class also belong the thousands of little lakelets scattered over the Northern States, which are confined on all sides by banks of drift-material, and fill nearly every depression and hollow in the huge banks of glacier-worn *débris*—known as *till*, *kaims*, *eskers*, etc., scattered so plentifully throughout our Northern country. We have seen many of these pretty little lakelets through New York, Ohio, and westward. Near Plainfield, New Jersey, scores may be passed in a morning's walk. At the latter place they occupy the hollows and dells in the drift, which is there of great thickness, and formed not only from the Triassic sandstone which underlies it, but also to a large extent from the limestone and gneiss found in place only in the northern portion of the State. Intermingled with these are many blocks of the peculiar reddish conglomerate found *in situ* in Morris County, which show unmistakably the direction from which the drift has traveled. Many of these stones are glacier-worn, and have without doubt been transported from their northern homes by the agency of ice; not in one or two isolated instances, but in sufficient quantity to cover the country for miles in extent. These little lakelets, becoming filled with vegetable matter, form peat-bogs, which promise to become of considerable agricultural value in the future; these peat-bogs not only contain many wonderful things for the eyes of those who are fortunate enough to possess a microscope, but also in them are sometimes found the bones of the huge mastodon, which at no very distant time inhabited this continent.

3. The formation of lakes by a sinking of their bottoms, although at first sight seeming to be the simplest and most common mode of their formation, is really the most unusual. Lake Superior is described as filling one of these depressions, as the rocks on its shores are found to dip toward the centre of the lake, and the basin seems to have been formed by a subsidence at that point, although greatly modified in after-time by the erosion of the ice during the glacial period. The valley into which the Jordan empties is another such region of subsidence.

No description has been given of the newly-discovered lakes of Central Africa, sufficiently accurate to decide to which mode of formation they owe their origin, but, as they are situated in the tropics, it will probably be found that, like Lake Superior, they fill synclinal valleys.

To this category belong also the truly great lakes which existed in our Western country during Tertiary times, which in the lapse of ages became filled with mud and silt, and now form the greater portion of the rich Territories of Nebraska, Dakota, etc. In this region are found, in great numbers, the remains of the huge animals which lived in these ancient lakes, and fed on the luxuriant tropical vegetation that overhung their banks.

The well-known Salt Lake of Utah is another example of a lake filling an area of depression, and was of far greater extent in past time, as is very plainly shown by the lines of ancient terraces which are so sharply drawn between Ogden and Salt Lake City, nearly a thousand feet above the present level of the lake.

4. Lakes of the fourth class, such as owe their formation to volcanic action, are found occupying the bowl-shaped craters of ancient volcanoes, which, as their fires became extinct, furnished convenient reservoirs for the accumulation of water, and in this manner sometimes formed lakes of considerable extent. Streams of lava, also, when they chance to flow in such a manner as to obstruct the drainage of a valley, may serve as a dam, above which the waters soon accumulate and form a lake.

Besides the kinds of lakes which we have enumerated, there are others, which are of rare occurrence and exceptional in their mode of formation; such is the beautiful little lake in Switzerland known as the Märjelen-See, which is formed by the glacier of the Aletsch blocking up the mouth of a tributary valley, and thus forming a wall of ice above which the waters accumulate. This ice-dam breaks away every few years, and allows the complete and rapid drainage of the lake, which often causes great inundations of the valley below. In ancient times a similar ice-dam existed in the valley of Glen Roy, Scotland, as has been shown by Lyell, which, by damming back the waters, formed a lake similar to the Märjelen-See. The waves of this ancient glacial lake chafed and wore its banks, and thus formed terraces at different levels, in the same manner as we often see the little ripples on the pools of water by the wayside cut their soft, muddy banks into terraces, so that, when the water is evaporated by the heat of the sun, their sides are left in a series of little steps; in the same manner, but on a far grander scale, the terraces were formed which are known as the Parallel Roads of Glen Roy, that have gained a world-wide fame both in science and story.

In our own country we sometimes find lakes which owe their existence to the industry of the beavers, who often build their dams in our streams, and sometimes form shallow lakes of considerable extent.

The lakes to which we have devoted the greatest attention, and which are at the same time the most common and the most interesting, are those which fill glacier-worn rock-basins, to which we hope that our little article will attract the attention of some one who will give us more light on these wonderful pictures, now but imperfectly illuminated.

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# AMPHIBIOUS FISHES.[1]

By E. SAUVAGE.

IN the swamps of the Gambia, after they have been dried by the tropical sun, there are to be found here and there beneath the surface clods of earth uniform in shape, and usually about the size of a man's two fists. These clods inclose living animals, which have been led by instinct to hide themselves away toward the close of the rainy season, and before the coming of the season of drought, by burying themselves in the mud while it was yet soft, and before it had been hardened by the scorching rays of the sun.

On breaking one of these lumps of mud, it is found to be a sort of pouch or cocoon, with thin walls, and with projections here and there corresponding to the form of the animal concealed within. Its larger end is rounded, but its narrower end is closed by a slightly convex lid with a narrow opening in the centre. If the surface of the cocoon be even gently touched, a pretty loud cry is heard which Natterer has compared to the mewing of a cat.

For a long time it was supposed that the animal buried itself amid the leaves which surround its protecting sheath. In a special memoir published in the Bulletins of the St. Petersburg Academy of Sciences, Leuckart expressed the opinion that the epidermis, by becoming detached, supplied the materials for this envelope. But since his time it has been demonstrated that the cocoon is formed from a dense secretion of mucus; such is the result of observations made by Paulson and Richard Owen, and repeated by Auguste Duméril, Professor of Ichthyology at the Museum. He has himself witnessed the formation of the cocoon, and his description of the process we repeat here in his own words. He says:

> "Two protopteri, that had been restored to freedom by the gradual softening of the clods in which they had been inclosed, evinced signs, after living for a month in an aquarium, that the time had come for them to seek, in the soft earth covered by the water, the shelter which they require during the dry season. Their restlessness, their abundant secretion of mucus, their attempts at burrowing, all showed an irresistible desire to find a medium different from that in which they then lived.

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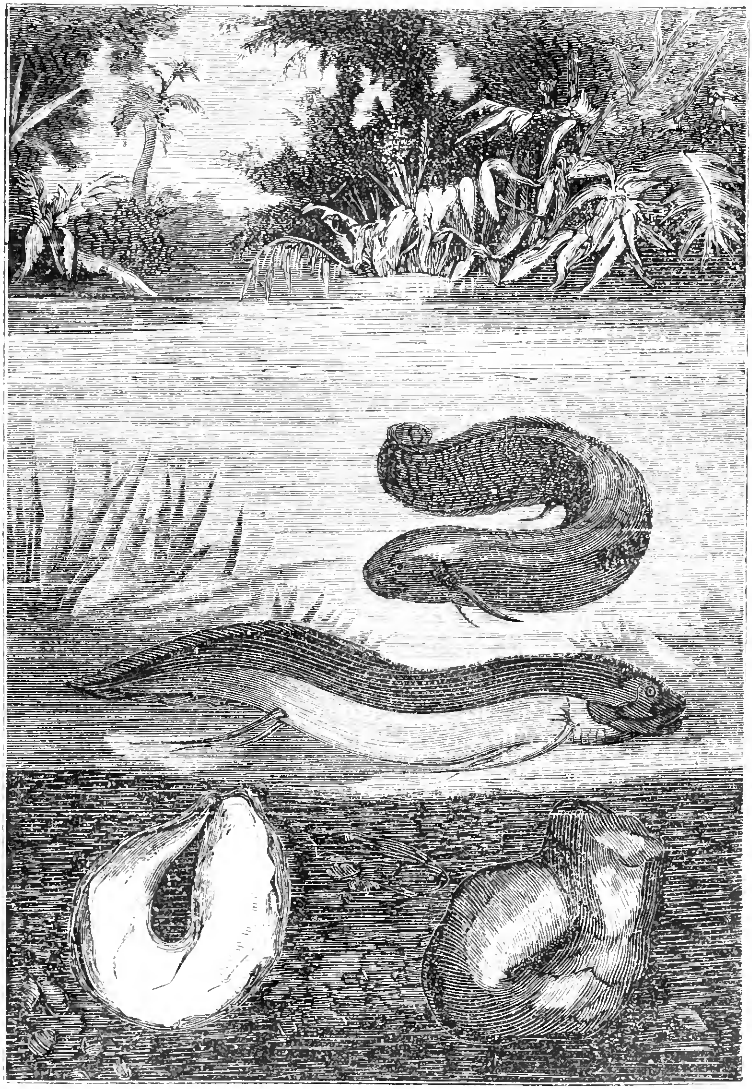
[1] Translated from the French, by J. Fitzgerald, A. M.

"I therefore took pains to surround them with conditions analogous to those they meet with when, after the water has retreated, the soil first becomes dry, and then hardens. The water in the aquarium was drawn off little by little as soon as the animals had burrowed into the mud. Three weeks had scarcely passed, and already the hardened earth showed a number of cracks; through these a small quantity of air is admitted, which supports respiration.



"On the seventieth day I examined the earth, and found that the two animals had met with such conditions as enabled them successfully to live through the artificially-produced dry season: they were enveloped in cocoons, and were full of life, as was shown by their motion on being touched ever so lightly.

"Thus the cocoon is a protecting sheath formed of the mucous secretion. The abundant secretion of mucus, in the first place, coats and strengthens the walls of the burrow made by the protopterus, and hence the subterraneous canal which it had excavated had its sides smooth, and as it were polished. Then, after the animal has reached the required depth, the secretion becomes still more abundant, and the mucus dries, forming a membranaceous envelope of remarkable structure."

The animal doubles itself up in its envelope, the tail being brought up in front of the head; the mouth is free, and through it passes the air needed for respiration, which, of course, is exclusively pulmonary, owing to the conditions in which the animal lives. In fact, the protopterus is able to respire in two ways, viz., either directly in the atmosphere, or indirectly by separating dissolved oxygen from water by means of its gills.

The external openings to the latter are two small apertures, one on each side of the neck. Each of these gives access to a chamber of moderate capacity, in which are floating certain filamentous appendages. On these are distributed the blood-vessels, which constitute but ill-developed tufts. In water, the animal respires by means of these; when it lives in its burrow, it respires by means of its lung.

Most fishes have, beneath the vertebral column, a sort of capsule, which seems to act the part of a floating apparatus. By means of this, the fish can rise in the water or descend at pleasure; it is known as the air-bladder. The sounds emitted by certain fishes, *Triglæ*, for example, are caused by vibrations communicated to the gases in this organ.

In the protopterus the air-bladder discharges the physiological functions of a lung when the animal can no longer respire through the gills. To attain this end, it divides up into a number of little cellular lobes, over the walls of which are spread a multitude of blood-vessels, containing blood to be oxygenated, though it is only partially venous. To prevent mixture of the two kinds of blood, that which has respired the oxygen and that which has discharged its physiological function, the auricle becomes divided in two by a partition. The left chamber receives the red blood, just as in the higher animals. A muscular *frænum*, or fold, forming a sort of rudimentary septum, rises from the floor of the ventricle; this *frænum* acts as a piston, preventing the return of the blood into the vessels by contracting when the heart contracts.

The air enters either through the mouth or through the nostrils, which debouch near the posterior margin of the upper lip; thence it passes into a trachea, which traverses the wall of the œsophagus; finally, having entered a sort of membranous sac, through two large openings, it reaches the lungs, whereof there are two, and which are like the lungs of serpents.

These singular animals, being, as we have said, truly amphibious, have received from naturalists the expressive name of *Dipnoi*, a term formed from two Greek words, meaning animals with twofold respiration.

Two genera, each comprising only one species, make up this subclass *Dipnoi*. Gambia, Zanzibar, Senegal, the region of the White Nile, and the Niger, are the native haunts of the African species, the *Protopterus annectens*, or *anguilliformis*; the other species, *Lepidosiren paradoxa*, is found in the valley of the Amazonas.

The latter species is but ill represented in collections; there are in Europe only a very few specimens. According to Mr. Bates, the natives call it *zambaki mboya*; this naturalist says that the *Lepidosiren* has even penetrated to the great lakes in the vicinity of the Tapajos and the Madeira. M. de Castelnau has caught this animal in a marsh on the left bank of the Amazonas, above Villanova, at a place called Caracauca.

In *Lepidosiren* the tail is pointed; the pectoral and ventral fins, which stand far apart, are not long, and consist of a single ray, not divided into segments. The general form is that of an eel, with two threads hanging on each side. In color the animal is dark brown-gray, or olive, with round spots of lighter color, about the size of the scales, and indistinct on the head and the middle of the back. The species appears to grow to the length of about one metre.

The protopterus, or African representative of the group, is olive-green in color, this tint being varied with a number of irregular brown or blackish spots. The lower portions are violet. The young are marked with fine lines of light color, which cross each other, forming a regular network. The extremity of the tail is tapering. The pectoral and ventral fins are long, and consist of one ray made up of jointed segments. The bones of the skeleton are of a green hue.

For our first acquaintance with these animals we are indebted to the naturalist Natterer, who, during his visit to Brazil, obtained two specimens, which he placed in the Vienna Museum. For a long time the *Protopterus* and *Lepidosiren* were classed with those batrachians in which the tail persists, as in the axolotl. Later they were considered as forming a sort of intermediate class between reptiles and fishes, and as forming the connecting link between the two. At present naturalists class *Lepidosiren* and *Protopterus* among fishes.

The *Dipnoi* are not the only class of animals that bury themselves in the dried-up mud after the water has been evaporated by the heat of summer. There is another fish that does the same—the mud-fish (*Amia*), which is found in the fresh waters of the United States. The *Amia*, too, is indisputably a *fish*. There appears to exist some relation between this animal's mode of life and the cellular structure of its air-bladder. Still, the *Amia* is not an amphibian, in the strict sense of the term. For, though its air-bladder resembles the lung of the serpent, it certainly receives only blood that has previously been aërated; hence we find in this animal no true aërial respiration alternating with strictly aquatic respiration.

But, though the *Amia* is not amphibious, and hence not to be considered in this place, nevertheless we must not omit to mention the fact that, while at present the genus is restricted within rather narrow geographical limits, it appears to have existed in Europe during the epoch known to geologists as the Middle Tertiary.

Thus there have been found at Oeningen (Switzerland), Kutschlin (Bohemia), Ménat and Armissan (France), fossil remains of *Cyclurus*, which has a close affinity with *Amia*. It is highly probable, not to say certain, that these fishes buried themselves in the mud during the dry season. The little tertiary lakes of Limagne appear to have undergone in past times alternations of drought and humidity, like the marshes of tropical and inter-tropical countries.

The presence in Europe of a genus closely allied to the *Amia* of America would seem to show that, at a relatively late period, these two divisions of the world were connected. The study of tertiary insects, to which E. Oustalet has devoted himself, and a thorough investigation of fossil fishes, would, we think, tend greatly to confirm Oswald Heer's hypothesis, according to which an Atlantis—not an historical Atlantis, as understood by Plato, but a geological Atlantis—connected the north of Europe with America toward the close of the great Tertiary epoch.

# INDUSTRIAL APPLICATIONS OF SOLAR HEAT.[1]

By L. SIMONIN.

THE history of burning-mirrors of brass is known. At Rome the sacred fire was lighted with apparatus of this kind, and Archimedes fired the ships which were blockading Syracuse by concentrating upon them the sun's rays by means of a large reflector. Buffon repeated successfully the experiments of Archimedes. With a mirror of very slight curvature, consisting of a number of pieces of looking-glass, he set fire, at some distance, to fir and beech planks, melted tin and silver, and brought iron to a red heat. Saussure later accumulated, by means of superimposed inclosures of glass, the sun's heat up to a temperature exceeding that of boiling water, and Sir John Herschel repeated these experiments at the Cape of Good Hope at various times between 1834 and 1838. At the same period the French physicist Pouillet was engaged at Paris in measuring the calorific intensity of solar radiation, arriving at the conclusion that the heat emitted

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[1] Translated from the French, by J. Fitzgerald, A. M.

from the sun and poured down upon the earth in one year would suffice to melt a sheet of ice thirty metres thick, and enveloping the entire globe.

About the year 1860, M. Mouchot, then Professor of Mathematics in the Lycée of Alençon, being stimulated by the researches of Pouillet as well as by those of Melloni, the ablest of Italian physicists, who has made experiments of incomparable precision upon the transmission of heat, boldly attacked the question of the utilization of the sun's heat. The mechanical equivalent of heat had at length been determined. Thanks to Melloni, we already knew the quantity of caloric which different bodies, as glass, when reduced to thin laminæ, suffer to pass through, as also the difference in the reflecting power of polished metallic surfaces according to the nature of the metals, employed. But to measure the amount of *vis viva* transmitted daily from the sun to the earth, and, more Utopian still, to concentrate, at little cost, the sun's rays, so as to realize all the effects of which they are capable, were objects the attainment of which was henceforth insured, though Buffon and Saussure had failed, owing to the insufficiency of the data at their command. The question is now merely a matter of calculation, an application of well-known physical laws.

In order to concentrate to any useful purpose the sun's rays, there was need of a receiver which should be of moderate size and reasonable cost. After sundry attempts, one of which was with an apparatus resembling that of Saussure, Mouchot contrived a vertical boiler of copper, blackened on the outside, covered with three concentric bell-glasses, and resting on some bad conductor of heat, as sand, brick, or wood. Soon he increased the power of his apparatus by the addition of a metallic reflector, which enabled him to dispense with two of the three bell-glasses. With this apparatus he considerably raised the temperature of the water in the boiler, reduced it to vapor, melted sulphur, the liquefaction temperature of which is 116° C., and after twenty minutes of insolation brought the empty boiler up to the temperature of 200° C.

With this reflector a few seconds suffice to set on fire a heap of shavings or a piece of board. In a glass vessel placed at the focus of the reflector and inclosed in another vessel of glass, one kilogramme of tin has been melted in two minutes; the same quantity of lead took five minutes, and of zinc, six. The fusion-point of these three metals is 235°, 335°, and 475° C. respectively. With spherical or parabolic mirrors, whose focus is a point, and not a line, as in the conical or cylindrical mirrors employed in the foregoing experiments, the concentration of solar heat would have been still stronger.

While engaged in these investigations, the ingenious experimenter brought out his *Marmite Solaire*, a cylindrical glass vessel, in which is placed another cylinder of copper or of wrought-iron blackened on the outside, and resting on the bottom of the glass receiver. The whole is covered with a glass lid. A cylindrical reflector of silver directs the sun's rays upon the apparatus. With this *marmite* it takes less than four hours to prepare an excellent *pot-au-feu*, consisting of one kilogramme of beef and a quantity of vegetables, the whole being perfectly cooked, and very palatable, owing to the fact of the heat being applied with great regularity.

In this form of marmite, now superseded by a simple glass vessel fixed at the focus of a conical mirror of silver-plated brass, fruits, potatoes, all sorts of legumes, meats, and grains, are cooked by solar heat. So, too, an infusion of tea or coffee can be readily prepared, and for this purpose we may employ one of those bottles of colored glass in which Lyons beer is put up. To cook legumes or grains rapidly, a different course may be taken. A closed vessel containing water is set in the focus of the reflector, and, when the liquid begins to boil, the upper portion of the vessel is connected by a tube with the bottom of another containing the legumes or grains, which are quickly cooked by the steam.

To transform the marmite into an oven, a disk of wrought-iron is placed beneath the glass lid, and in less than three hours a kilogramme of bread is baked. The crust is hard and brown, and the pith light and well raised, as with bread baked in an ordinary oven.

The roasting of meat, not requiring the same amount of heat as does the vaporization of an equal weight of water, can be performed in the open air, by the action of the solar reflector alone, the piece of beef, veal, or mutton being fixed upon a spit. In less than an hour we have in this way a very fine roast. The use of butter must be avoided, lest the chemical rays, by transforming the butter into butyric acid, should spoil the flavor of the meat. By interposing a pane of green or red glass we can intercept the chemical rays which cause this fermentation, and then the result leaves nothing to be desired.

By substituting for the two lids of the solar marmite an alembic-head, the apparatus can be used for the purposes of distillation. To this end the alembic-head is connected, by an horizontal tube, with a worm, the latter descending in the form of a helix and dipping into a constant current of cold water, while the metallic vessel, containing two litres of wine, is inclosed in the glass cylinder and set in the focus of the reflector. The alcohol is collected after forty minutes of exposure to the sun. Inasmuch as the apparatus grows hot slowly and continuously, the alcohol is highly concentrated and possesses a very agreeable aroma.

In all the foregoing experiments, M. Mouchot at first used concave silver mirrors, cylindro-parabolic in form, i. e., cylindrical mirrors whose base-line is an open curve resembling a parabola. The reflecting power of cylindrical mirrors increases in proportion to their aperture, and hence the time required, for instance, to boil a litre of water is inversely as the aperture of the mirror, i. e., the greater the aperture the shorter the time. But later the inventor has employed only conical mirrors, and in these the insolation surface is quadrupled when the diameter of the mirror is doubled.

Mouchot's researches did not end here. He proposed further to obtain mechanical effects with solar heat, and in the beginning of August, 1866, he put in operation at Paris the first machine of this kind.

In the mean time Ericsson was studying these same problems, without knowing anything about Mouchot's experiments. Starting from the facts collected by Herschel and Pouillet, Ericsson, in the first place, estimated the action of the sun upon a surface of nine square metres to be sufficient to vaporize eight litres of water; consequently it would be equal to one horse-power. From these premises he deduces striking consequences, as, for instance, that the solar heat falling on the roofs of Philadelphia alone would suffice to drive 5,000 steam-engines of twenty horse-power each. Then, having demonstrated that upon one square mile, using only one-half of the surface and devoting the remainder to buildings, roads, etc., we can drive 64,800 steam-engines, each of a hundred horse-power, simply by the heat radiating from the sun, he adds these remarkable words: "Archimedes, having completed his calculation of the force of a lever, said that he could move the earth; I affirm that the concentration of the heat radiated by the sun would produce a force capable of stopping the earth in its course." Again: "In England they are beginning to calculate the time when the coal will give out, though coal-mines are, so to speak, of recent exploitation. A few thousands of years—drops in the ocean of time—will exhaust the coal-mines of Europe, unless, meanwhile, recourse is had to the aid of the sun. True, the sun's beams do not every day reach the surface of the earth; but, when the great magazine is opened which shall supply heat gratuitously without cost of transportation, the prudent engineer will know how to provide a reserve against cloudy days. At the same time we would observe that a large proportion of the earth's surface is illumined by an ever-radiant sun. The solar engine's sphere of activity is as great as its dynamic power is considerable." Mr. Ericsson, who, besides genius, possesses wealth and a long experience, will doubtless some day take up again his studies upon the mechanical application of solar heat. Meanwhile, we must state what has been done in this direction by a Frenchman.

The traveler who visits the library of Tours sees in the court-yard in front a strange-looking apparatus. Imagine an immense truncated cone, a mammoth lamp-shade, with its concavity directed skyward. This apparatus is of copper, coated on the inside with a very thin silver-leaf. On the small base of the truncated cone rests a copper cylinder, blackened on the outside, its vertical axis being identical with that of the cone. This cylinder, surrounded as it were by a great collar, terminates above in a hemispherical cap, so that it looks like an enormous thimble, and is covered with a bell-glass of the same shape.

This curious apparatus is nothing else but a solar receiver, or, in other words, a boiler, in which water is made to boil by the heat-rays of the sun. This steam-generator is designed to raise water to the boiling-point and beyond, by means of the solar rays, which are thrown upon the cylinder by the silvered inner surface of the conical reflector. The boiler receives water up to two-thirds of its capacity through a feed-pipe. A glass tube and a steam-gauge communicating with the inside of the generator, and attached to the outside of the reflector, indicate both the level of the water and the pressure of the steam. Finally, there is a safety-valve to let off the steam when the pressure is greater than is desired. Thus the engine offers all desirable safety, and may be provided with all the accessories of a steam-boiler.

The reflector, which is the main portion of the generator, has a diameter of 2.60 metres at its large, and one metre at its small base, and is eighty centimetres in height, giving four square metres of reflecting surface, or of insolation. The interior walls are lined with burnished silver, because that metal is the best reflector of the heat-rays; still brass with a light coating of silver would also serve the purpose. The inclination of the walls of the apparatus to its axis measures 45°. Even the ancients were aware that this is the best form for this kind of metallic mirrors with linear focus, inasmuch as the incident rays parallel to the axis are reflected perpendicularly to the same, and thus give a focus of maximum intensity.

The boiler is of copper, which of all the common metals is the best conductor of heat; it is blackened on the outside, because black possesses the property of absorbing all the heat-rays, just as white reflects them; and it is inclosed in a glass envelope, glass being the most diathermanous of all bodies—that is to say, the most permeable by the rays of luminous heat. Glass further possesses the property of resisting the exit of these same rays after they have been transformed into dark rays on the blackened surface of the boiler. None of these applications of physical laws present any novelty; people reduced them to practice instinctively, as it were, before men of science could assign the reasons. Here the arts of cookery and of gardening, and the processes for warming our rooms, did not wait for the experiments of the physicist. Saussure himself started from these data in his researches; but the inventor needed the discoveries of modern physics in order to give to these applications a rigorous formula.

The boiler proper of the Tours solar engine consists of two concentric bells of copper, the larger one, which alone is visible, having the same height as the mirror, i. e., eighty centimetres, and the smaller or inner one fifty centimetres; their respective diameters are twenty-eight and twenty-two centimetres. The thickness of the metal is only three millimetres. The feed-water lies between the two envelopes, forming an annular envelope three centimetres in thickness. Thus the volume of liquid is twenty litres, and the steam-chamber has a capacity of ten litres. The inner envelope is empty. Into it pass the steam-pipe and the feed-pipe of the boiler. To the steam-pipe are attached the gauge and the safety-valve. The bell-glass covering the boiler is eighty-five centimetres high, forty centimetres in diameter, and five millimetres in thickness. There is everywhere a space of five centimetres between its walls and those of the boiler, and this space is filled with a layer of very hot air.

The earth, owing to its diurnal and annual revolution, does not occupy the same position with regard to the sun at all hours of the day, or in all seasons of the year. This being the case, the generator is so contrived as to revolve 15°, or one twenty-fourth of its circumference, hourly around an axis parallel to the earth's axis, i. e., so as to follow the apparent diurnal motion of the sun, and to incline gradually on this axis in proportion to the solar declination. Hence the intensity of the utilized heat is always nearly the same, whatever the hour of the day or the season of the year, inasmuch as the apparatus is always so arranged as to reflect with the least possible loss all the rays emitted by the sun. This double motion of the generator is effected by a very simple contrivance.

The generator just described is the one which M. Mouchot was enabled three years and a half ago to set up at Tours, the Conseil Général of Indre-et-Loire having provided the funds. It has yielded curious results, some of which are worthy of being recorded here, though before long they will be surpassed, when some improvements have been made in the apparatus. On May 8, 1875, the weather being fine, twenty litres of water at 20° C. temperature was introduced into the boiler at 8.30 A. M., and took only forty minutes to produce steam with a pressure of two atmospheres; in other words, a temperature of 121° C. was obtained, which is 21 centigrade degrees above boiling-point. This steam then quickly acquired a pressure of five atmospheres. This was the safety limit of the strength of the apparatus: if the process had been carried any further the boiler would have exploded. Toward noon on the same day, with fifteen litres of water in the boiler, steam at 100° C., i. e., a pressure of one atmosphere, was raised in less than fifteen minutes to five atmospheres—a temperature of 153° C. Finally, on July 22d, about one hour after mid-day, the heat being exceptionally great, the apparatus reduced to vapor five litres of water per hour, which is equal to one hundred and forty litres of steam per minute, or half a horse-power.[1]

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[1] A maker of instruments of precision, J. Salleron, who constructed the solar apparatus which was presented to the Institut last year, lately wrote to me as follows: "I have driven a small model steam-engine, with the steam generated in the boiler of this new generator, and M. Noel, Professor of Physics in the Vendôme Lycée, put the same engine in operation on January 5th last. The water began to boil after twenty-eight minutes, the hour being noon, and the temperature of the surrounding air near 0° C."

A steam-engine consists of two principal parts, the boiler and the engine proper, or motor. We suppose that with the boiler employed at Tours we can use the common motors; this is one of the advantages possessed by the solar apparatus, viz., that it does not require a special form of motor. At first the inventor employed for his demonstrations a double-acting engine, without either condensation or detention of steam, the cylinder of which had a capacity of one-third of a litre. This engine performed eighty strokes per minute, with a steady pressure of one atmosphere; it continued to work even under a slightly-clouded sun. This was later superseded by a rotary engine, that is, an engine with revolving cylinder, which avoids all transmission of movement; but the system is faulty. Yet this engine worked very well, driving at high velocity a little pump for raising water; the pump, however, being of weak construction, became disabled. It is a pity that the inventor has never measured the real work performed by his engine, by means of a dynamometer.

The solar reflector, being first of all a furnace using fuel that costs nothing, is not only of use as a means of developing motive force, but can also be employed for a multitude of purposes—for instance, distilling water to make it fit for drinking, concentrating and crystallizing saline solutions, preparing alcohol, etc. Five litres of wine can be distilled in a quarter of an hour by passing the vapor from the apparatus into a still. The manufacture of alcohol from grain, sugar-cane, or beet-root, would be equally easy. The steam generated by this apparatus can also be employed for cooking fodder for cattle. M. Mouchot has devised a form of small marmites, quite different from his large steam-generator. These can be used by hunters for preparing their meals, and explorers of great deserts will now have something besides camel or buffalo chips for cooking their victuals.

Many and varied are the uses of this curious invention. The aëronaut can with its aid propel his air-ship. Hot-air motors and ammonia engines will be benefited by the use of the solar receiver; but it is especially in tropical countries that it is destined to find immediate employment, in driving the various kinds of machinery used in sugar and cotton plantations, in distilling impure water to make it fit for drinking, in crystallizing saline and saccharine solutions, in pumping water of irrigation, in manufacturing ice by means of the Carré machine, etc. In those countries fuel is scarce, firewood is not abundant, and coal, which has to be imported from a distance, often from the mines of England, commands an exorbitant price. Already in southern countries sea-salt is obtained purely by the action of solar heat. In Chili and in Mauritius, salt-marshes are divided into compartments, with walls and roof of glass, in order to promote evaporation; so in the famous nitre-beds of Iquique, on the coast of Peru, the salt might be crystallized by solar heat alone.

The cost of a solar apparatus of half a horse-power, like that at Tours, does not exceed fifteen hundred francs, and, when the manufacture is carried on upon a large scale, will be much less. By substituting for the silver plate, which is the most costly portion of the reflector, brass with a thin coat of silver, which will serve the purpose equally well, a considerable reduction of cost is effected.

As the insolation surface, and consequently the power of the apparatus, is quadrupled when the diameter of the mirror is doubled, it will be easy to construct large generators without adding very much to the cost or complicating the mechanism. The one thing to be avoided in this case will be too great intensity of heat. It cannot be objected that the conical reflector takes up too much room, for a common steam-engine occupies considerable space likewise with its long boilers and its high chimney; as for the motor, properly so called, and the contrivances for transmitting the power, they are the same in both cases.

The strongest winds, at least in our latitudes, have no action on the reflection of the solar heat, or upon the mirror itself, which is not shaken by them. This is an important point, for this is an apparatus which must always be exposed in the open air. In regions where the wind-storms are more severe than they are here, the reflector might be staid and strengthened with iron ribs, so as to resist the most violent cyclones. It has been demonstrated that the bell-glass, even when highly heated by the direct radiation from the boiler, is in no danger of breaking, even when a cold rain falls upon it, and that it is even proof against hailstones; and now that a process has been invented for tempering glass and making it almost unbreakable, we can without difficulty obtain bell-glasses strong enough for any emergency.

Experience will hereafter lead to many improvements now unthought of; but even as it stands to-day the solar engine at Tours is ready to pass from the speculations of theory to the application of practice. It is neither over-costly, nor difficult to set up, nor so complicated as to require great skill in managing it; and, from whatever point of view we regard it, it meets and overcomes all objections. We may say that it lends itself to every industrial use in which solar heat can be employed, especially in tropical countries where the absence of all kinds of fuel for industrial uses is severely felt. In the not distant future, in other countries, too, there will exist no other fuel than the sun, no other engines than those driven by solar heat. By that time no doubt the means of storing up this heat will have been discovered, for in our latitudes we shall have to make provision against cloudy days and seasons of rain, which unfortunately constitute the major part of the year.

It may appear to be a pleasant paradox to say that future generations, after the coal-mines have been exhausted, will have recourse to the sun for the heat and energy needed in manufacture and in domestic economy. Still, nothing could be plainer than this. In our day, when it is probable that force, motion, gravity, heat, light, electricity, magnetism, are simply modifications of one and the same agent, and the effect of the vibrations of that impalpable and invisible fluid known as ether, the assertion that the sun is the only fuel, the only force, must not call forth anywhere the smile of incredulity. All fuels, all forces, are to be regarded as only parts of the sun's heat. What is coal? Fossil carbon. And was not this carbon fixed in plants by the sun's heat, of which it is the equivalent? Under the action of solar radiations the carbonic acid in the atmosphere is decomposed on contact with plants; the carbon is fixed in the plant, and the oxygen goes back into the air to serve for the respiration of animals. Hence, no sun, no vegetation; no vegetation, no carbon; no carbon, no coal. Coal, in burning, gives up the solar heat which was stored up in it, and therefore it was that, on seeing a locomotive engine move, Stephenson said: "It is not the coal that drives this engine, it is the sun's heat stored up in the coal thousands of ages ago; locomotives are but the horses of the sun." We might make a like comparison with respect to wine and the alcohol it contains; and the Bordelais use no mere figure of speech when they speak of their admirable Sauterne wine as being "bottled sunshine."

When water rises in the shape of vapor, what is it that causes it to ascend? The heat of the sun. If it comes down as rain, forming torrents and brooks which feed our mill-races and drive our mills, what is it that turns the wheel? The sun, for it was the sun that in the first place raised the water. When the wind blows upon the sails of a windmill, or on the sails of a ship, what is it that drives the mill or propels the ship? The sun, for wind is simply an atmospheric current produced by the heating of a stratum of air which, being dilated by the sun, tends to an equilibrium with strata of the same density, and hence rises, while a volume of cooler air takes its place. And what are the tides, the propulsive power of which there is some thought of utilizing, whether directly by means of water-wheels, or indirectly by compressing air and so producing a constant supply of force? They are a portion of the heat of the sun, for the seas are formed by the coming together of all those torrents and rivers which descend into their common reservoir, the ocean. Then, too, the tides are the result of the combined attraction of sun and moon upon the earth. Thus we find that the sun is always and everywhere active.

It is, therefore, no paradox to regard the sun as the one source of fuel in the future, and as the reservoir of force to which generations to come will at no distant day have recourse. Hence it is that *savants* and great engineers, as Euclid, Archimedes, Hero, Salomon de Caus, Buffon, Saussure, Bélidor, Evans, Herschel, Pouillet, Ericsson, have in every age put to themselves the question how it might be possible to take from the sun a part of its heat for the benefit of this poor globe.

The world will not perish for want of coal, yet the coal-supply will fail, and that much sooner than Ericsson estimated, for the production doubles every ten or fifteen years. It will not take thousands of years to exhaust the European coal-mines, but only hundreds, and not very many hundreds either. In England, as appears from recent calculations, the supply will have been consumed in two or three centuries at the farthest. Belgium, Germany, France, and the other countries of Europe, are no better off. The United States of America and the north of China have coal enough to last for one thousand years, and that is all. We must then have recourse to the sun.

It will perhaps be said, "There is electricity." Electricity, as a mechanical agent, is too costly; to produce electricity we have to consume copper, zinc, and acids. Now, one kilogramme of copper, zinc, or acid represents several kilogrammes of coal expended in procuring it. In reducing copper-ore according to the Welch method, sixteen kilogrammes of coal is consumed for each kilogramme of copper obtained. Hence it were reasoning in a vicious circle to suppose that electrical or electro-magnetic machines can usefully or economically take the place of steam-engines. There is only one case in which this conclusion would be weakened; namely, if with a thermo-electric pile we should succeed in decomposing water into its elements, oxygen and hydrogen, at little or no expense. The problem would then be solved, for this would place in the hands of all the two greatest sources of light, heat, and force—oxygen and hydrogen. But, even then, to what should we owe this unexpected solution? To the sun, for it is only by the aid of a thermo-electric pile (wherein we suppose electricity to be produced by solar heat) that we could economically decompose oxygen and hydrogen; else it would require at least as much heat to dissociate them as they would yield on recombining—a *petitio principii* overlooked by those simple inventors who persist in attempting, by means of ordinary electric piles, to solve the great problem of economical motors and the fuel of the future.

As for directly storing up solar heat in good conductors or absorbents of heat which are then to be insulated—for instance, receiving the heat in porous black stones which are first exposed to the sun and afterward thrown into a great reservoir, just as snow is piled up in the ice-house—it involves no impossibility. These stones could be thrown into water, if needs were, and in this way we might easily attain or surpass the temperature of boiling water.

Straw, sawdust, wool, feathers, confined air, are insulating substances which retain heat. We might surround with a double envelope of this kind the reservoir holding the sun-heated stones, and in this way we might have our store of solar heat, as now we have our store of ice. It is one problem whether we have to retain cold or to retain heat. Now, ice keeps very well even when stowed in the hold of a vessel; a little sawdust and careful stowage do the whole work.

The same means will serve in storing solar heat, and, if need be, shipping it to a distance. We have barely outlined the idea, but certain we are that at the proper time the scientific man will appear who shall discover a practical method of doing this.

The sun, as it would appear, will be the fuel of the future, and one might say that this was foreseen by the great encyclopædic scholar of the middle ages, Dante, when in his incomparable poem he said, "*Guarda il calor del sol che si fa vino*"—"Look at the sun's heat which changes into wine"—as though he meant to say, into all that is force, all that is life, all that is light.—*Revue des Deux Mondes.*

# THE REVIVED THEORY OF PHLOGISTON.

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IN 1781–'83, Cavendish showed that when inflammable air or hydrogen, and dephlogisticated air or oxygen, are exploded together in certain proportions, "almost the whole of the inflammable and dephlogisticated air is converted into pure water," or, as he elsewhere expresses it, "is turned into water."

On June 24, 1783, the experiment of Cavendish was repeated on a larger scale and in a somewhat different form by Lavoisier, who not only confirmed the synthesis of the English chemist, but drew from it the conclusion—at first strongly contested, then rapidly acknowledged, and since never called into question—"that water consists of inflammable air united to dephlogisticated air," or that it is a compound of hydrogen and oxygen.

This conclusion, so opposite to his own preconception on the matter, Lavoisier subsequently confirmed by an analysis of water. He found that iron, heated to redness and exposed to the action of water-vapor, became changed, by an abstraction of oxygen from the water, into the self-same oxide of iron procurable by burning the metal in oxygen gas—the other constituent of the water, namely, its hydrogen, being freely liberated.

With the demonstration by Lavoisier of the composition of water began the triumph of that antiphlogistic theory which he had conceived, in a necessarily imperfect form, so far back as 1772, or before the discovery of oxygen, and had brought to completion by the aid of every successive step in pneumatic chemistry, achieved by himself or by others.

In 1785, the relationship to one another of hydrogen and water being then conclusively established, Berthollet declared himself a convert to the new theory of combustion put forward by his countryman.

Fourcroy next gave in his adhesion; and soon afterward De Morveau, invited to Paris expressly to be reasoned with by Lavoisier, succumbed to the reasons set before him. The four chemists then associated themselves together, and, in spite of a strong though short-lived opposition both in England and Germany, succeeded in obtaining for *La Chimie Française* an all but universal recognition.

The principal articles of the new or antiphlogistic theory of combustion propounded by Lavoisier are as follows: That combustible bodies in burning yield products of various kinds, solid in the case of phosphorus and the metals, liquid in the case of hydrogen, gaseous in the case of carbon and sulphur. That in every case the weight of the products formed by the burning is greater than the weight of the combustible burned. That the increase of weight is due to an addition of matter furnished to the combustible by the air in which its burning takes place. That bodies of which the weights are made up of the weights of two or more distinct kinds of matter are of necessity compound; whereas bodies of which the weights cannot be shown to be made up of the weights of two or more distinct kinds of matter are in effect simple or elementary. That, inasmuch as the weights of the products furnished by the burning of different combustibles are made up of the weights of the combustible burned and of the oxygen consumed in the burning, these products are compound bodies—oxides in fact of the substances burned. That, inasmuch as given weights of many combustibles, as of hydrogen, sulphur, phosphorus, carbon, and the metals, are not apparently made up of the weights of two or more distinct kinds of matter, these particular combustibles are in effect elementary; as for the same reason is the oxygen with which in the act of burning they enter into combination. And, lastly, that combustion or burning consists in nothing else than in the union of combustible matter, simple or compound, with the empyreal matter, oxygen—the act of union being somehow attended by an evolution of light and heat. And, except that it would be necessary nowadays to explain how, in certain cases of combustion, the combustible enters into union not with oxygen, but with some analogue of oxygen, the above precise statement might equally well have been made by Lavoisier in 1785, or be made by one of ourselves at the present day.

Lavoisier's theory of combustion being known as the antiphlogistic theory, the question arises, What was the phlogistic theory to which it was opposed, and which it succeeded so completely in displacing? This phlogistic theory was founded and elaborated at the close of the seventeenth century by two German physicians, Becher and Stahl. Having exercised a scarcely-disputed authority over men's minds until the notorious defection in 1785, it preserved for some years longer a resolute though tortuous existence, and was to the last defended and approved by our own Priestley and Cavendish—who died, the former in 1804, and the latter in 1810.

The importance attached to the refutation of this theory may be judged of from the circumstance that, after the early experiments of Lavoisier on the composition and decomposition of water had been successfully repeated by a committee of the French Academy in 1790, a congratulatory meeting was held in Paris, at which Madame Lavoisier, attired as a priestess, burned on an altar Stahl's celebrated "Fundamenta Chemiæ Dogmaticæ et Experimentalis," solemn music playing a requiem the while. And the sort of estimation in which the Stahlian doctrines have since been held by chemists is fairly illustrated by a criticism of Sir J. Herschel, who, speaking of the phlogistic theory of chemistry, says that it "impeded the progress of the science, as far as a science of experiment can be impeded by a false theory, . . . . by involving the subject in a mist of visionary and hypothetical causes in place of the true acting principles." Possibly, however, this much-abused theory may yet prove to contain an element of permanent vitality and truth; anyhow the study of this earliest and most enduring of chemical theories can never be wholly devoid of interest to chemists.

To appreciate the merit of the phlogistic theory it is necessary to bear in mind the period of its announcement. Its originator, Becher, was born in 1625, and died a middle-aged but worn-out man in 1682, a few years before the publication of the "Principia." His more fortunate disciple, Stahl, who was born in 1660, and died in 1734, in his seventy-fifth year, though afforded a possibility of knowing, seems equally with Becher to have remained throughout his long career indifferent to the Newtonian principle that the weight of a body is proportionate to its quantity of matter—that loss of weight implies of necessity abstraction of matter, and increase of weight addition of matter. Whether or not the founders of the phlogistic theory conceived that change of matter in the way of kind might, equally with its change in point of quantity, be associated with an alteration in weight—and it must not be forgotten what pains Newton thought it necessary to take in order to show the contrary—certain it is, they attached very little importance to the changes of weight manifested by bodies undergoing the metamorphosis of combustion. It might be that when combustible charcoal was burned the weight of incombustible residue was less than the original weight of charcoal—it might be that when combustible lead was burned the weight of incombustible residue was greater than the original weight of metal—this was far too trifling an unlikeness to stand in the way of the paramount likeness presented by the two bodies. For the lead and charcoal had the common property of manifesting the wonderful energy of fire; they could alike suffer a loss of light and heat—that is, of phlogiston—by the deprivation of which they were alike changed into greater or less weights of inert incombustible residue.

And not only were these primitive students of the philosophy of combustion unconscious of the fact and meaning of the relationship in weight subsisting between the consuming and the consumed body, but they were altogether ignorant of the part played by the air in the phenomena which they so boldly and successfully attempted to explain. Torricelli's invention of the barometer, and Guericke's invention of the air-pump, were both, indeed, made during Beecher's early boyhood; but years had to elapse before the consequent idea of the materiality of air could be domiciled, as it were, in human understandings. And not until more than a century after Torricelli's discovery of the weight of air—not, indeed, until the time of the great pneumatic chemists, Black, Cavendish, Priestley, and Scheele—was it ever imagined that the aërial state, like the solid or liquid state, was a state common to many distinct kinds of matter; and that the weight or substance of a rigid solid might be largely contributed to by the weight or substance of some constituent having its independent existence in the aërial or gaseous form. The notion that 100 pounds of smithy-scales might consist of 73 pounds of iron and 27 pounds of a particular kind of air, and that 100 pounds of marble might consist of 56 pounds of lime and 44 pounds of another kind of air, was a notion utterly foreign to the elder philosophy. Air, it was allowed, might be rendered mephitic by one kind of contamination, and sulphurous by another, and inflammable by a third; it might even be absorbed in, and so add to the weight of, a porous solid, as water is absorbable by sand; but still air was ever indisputably air, essentially alike and unalterable in its mechanical and chemical oneness. This familiar conception had to be overcome, and the utterly strange notion of the largely aërial constitution of solid matter to be established in its stead, by the early pneumatic chemists, Black, Cavendish, and Bergmann, before the deficiencies rather than positive errors of the phlogistic theory could be perceived.

But long ere the foundation of modern chemistry had thus been laid, in 1756, by Black's discovery of fixed air or carbonic acid as a constituent of mild alkalies and limestone, those old German doctors, Beecher and Stahl, though ignorant of the nature of air, and neglectful of the import of gravity, had yet found something to say about the chemistry of combustion worthy of being defended a century afterward by men like Priestley and Cavendish—worthy, it is believed, of being recognized nearly two centuries afterward as the expression of a fundamental doctrine in chemical and cosmical philosophy. They pointed out, for example, that the different and seemingly unlike processes of burning, smouldering, calcining, rusting, and decaying, by which combustible is changed into incombustible matter, have a community of character; that combustible bodies possess in common a power or energy capable of being elicited and used, whereas incombustible bodies are devoid of any such energy or power; and, lastly, that the energy pertaining to combustible bodies is the same in all of them, and capable of being transferred from the combustible body which has it to an incombustible body which has it not, rendering the body that was energetic and combustible inert and incombustible, and the body that was inert and incombustible energetic and combustible, and further rendering some particular body combustible over and over again. That this is a fair representation of the views held by phlogistic chemists is readily recognizable by a study of chemical works written before the outbreak of the antiphlogistic revolution. After Lavoisier's challenge, the advocates of phlogiston, striving to make it account for a novel order of facts with which it had little or nothing to do, were driven to the most incongruous of positions; for, while Priestley wrote of inert nitrogen as phlogisticated air, Kirwan and others regarded inflammable hydrogen as being phlogiston itself in the isolated state. Very different is the view of phlogiston to be gathered from the writings of Dr. Watson, for example, who was appointed Professor of Chemistry at Cambridge in 1764, became Regius Professor of Divinity in 1771, and Bishop of Llandaff in 1782. This cultivated divine, indifferent, it is true, to the novel questions by which in less placid regions men's minds were so deeply stirred, amused the leisure of his dignified university life by writing scholarly accounts of the chemistry it had formerly been his province to teach; and in the first volume of his well-known "Chemical Essays," published in 1781, the following excellent account of phlogiston is to be found:

> "Notwithstanding all that perhaps can be said upon this subject, I am sensible the reader will be still ready to ask, *What is phlogiston?* You do not surely expect that chemistry should be able to present you with a handful of phlogiston, separated from an inflammable body; you may just as reasonably demand a handful of magnetism, gravity, or electricity, to be extracted from a magnetic, weighty, or electric body. There are powers in Nature which cannot otherwise become the objects of sense than by the effects they produce; and of this kind is phlogiston. But the following experiments will tend to render this perplexed subject somewhat more clear:
>
> "If you take a piece of *sulphur* and set it on fire it will burn entirely away, without leaving any ashes or yielding any soot. During the burning of the sulphur a copious vapor, powerfully affecting the organs of sight and smell, is dispersed. Means have been invented for collecting this vapor, and it is found to be a very strong acid. The acid thus procured from the burning of sulphur is incapable of being either burned by itself or of contributing toward the support of fire in other bodies; the sulphur, from which it was procured, was capable of both: there is a remarkable difference, then, between the acid procured from the sulphur and the sulphur itself. The acid cannot be the only constituent part of sulphur; it is evident that *something* else must have entered into its composition, by which it was rendered capable of combustion. This something is, from its most remarkable property, that of rendering a body combustible, properly enough denominated the food of fire, the *inflammable principle, the phlogiston*. . . . This inflammable principle or phlogiston is not one thing in animals, another in vegetables, another in minerals; it is absolutely the same in them all. This identity of phlogiston may be proved from a variety

of decisive experiments; I will select a few, which may at the same time confirm what has been advanced concerning the constituent parts of sulphur.

"From the analysis or decomposition of sulphur effected by burning, we have concluded that the constituent parts of sulphur are two—an *acid* which may be collected, and an *inflammable principle* which is dispersed. If the reader has yet acquired any real taste for chemical truths, he will wish to see this analysis confirmed by synthesis; that is, in common language, he will wish to see sulphur actually made by combining its acid with an inflammable principle. It seldom happens that chemists can reproduce the original bodies, though they combine together all the principles into which they have analyzed them; in the instance, however, before us, the reproduction of the original substance will be found complete.

"As the inflammable principle cannot be obtained in a palpable form separate from all other bodies, the only method by which we can attempt to unite it with the acid of sulphur must be by presenting to that acid some substance in which it is contained. Charcoal is such a substance; and by distilling powdered charcoal and the acid of sulphur together, we can procure a true yellow sulphur, in no wise to be distinguished from common sulphur. This sulphur is formed from the union of the acid with the phlogiston of the charcoal; and the charcoal may by this means be so entirely robbed of its phlogiston that it will be reduced to ashes, as if it had been burned. . . .

"I will in this place, by way of further illustration of the term phlogiston, add a word or two concerning the necessity of its union with a metallic earth, in order to constitute a metal. Lead, it has been observed, when melted in a strong fire, burns away like rotten wood; all its properties as a metal are destroyed, and it is reduced to ashes. If you expose the ashes of lead to a strong fire they will melt; but the melted substance will not be a *metal*, it will be a yellow or orange-colored *glass*. If you pound the glass, and mix it with charcoal-dust, or if you mix the ashes of the lead with charcoal-dust, and expose either mixture to a melting heat, you will obtain, not a *glass*, but a *metal*, in weight, color, consistency, and every other property, the same as lead. The ashes of lead melted *without* charcoal become *glass;* the ashes of lead melted *with* charcoal become a *metal.* The charcoal, then, must have communicated *something* to the ashes of lead, by which they are changed from a glass to a metal. Charcoal consists of but two things—of ashes and of phlogiston; the ashes of charcoal, though united with the ashes of lead, would only produce glass; it must, therefore, be the other constituent part of charcoal or phlogiston which is communicated to the ashes of lead, and by a union with which the ashes are restored to their metallic form. The ashes of lead can never be restored to their metallic form without their being united with *some* matter containing phlogiston, and they may be reduced in their metallic form by being united with *any* substance containing phlogiston in a proper state, whether that substance be derived from the animal, vegetable, or mineral kingdom; and thence we conclude, not only that phlogiston is a necessary part of a metal, but that phlogiston has an identity belonging to it, from whatever substance in Nature it be extracted. And this assertion still becomes more general, if we may believe that metallic ashes have been reduced to their metallic form, both by the solar rays and the electrical fire."

The foregoing account by Dr. Watson is almost a translation from Stahl's "Zymotechnica Fundamentalis, simulque experimentum novum sulphur verum arte producendi," in which he establishes what may be called the permanency of chemical substance—that metallic lead is reproducible from the ashes of lead, *sulphur verum* from the acid of sulphur. And, whether or not taking note of the oxidations and deoxidations effected, how little differently, even at the present day, would the actions referred to be described and explained! Is it not our habit to say that charcoal and sulphur and lead are bodies possessing potential chemical energy—that is, phlogiston; that, in the act of burning, their energy which was potential becomes kinetic or dynamical, and is dissipated in the form of light and heat; that the products of their burning (including the gaseous product now known to be furnished by the burning of charcoal) are substances devoid of chemical energy—that is, of phlogiston; that, when the acid substance furnished by burning sulphur is heated with charcoal, some energy of the unburnt charcoal is transferred to the burnt sulphur, just as some energy of a raised weight may be transferred to a fallen one, whereby the burnt sulphur is unburnt, provided with energy, and enabled to burn again, and the fallen weight is lifted up, provided with energy, and enabled to fall again; that the potential chemical energy of metallic lead did not originate in the lead, but is energy or phlogiston transferred thereto from the charcoal by which it was smelted; and, lastly, that the chemical energy of the charcoal itself, its capability of burning, its power of doing work, in one word, its phlogiston, is merely a portion of energy appropriated directly from the solar rays?

If this be a correct interpretation of the phlogistic doctrine, it is evident that the Stahlians, though ignorant of much that has since become known, were nevertheless cognizant of much that became afterward forgotten. For most of what has since become known mankind are indebted to the surpassing genius of Lavoisier; but the truth which he established, alike with that which he subverted, is now recognizable as a partial truth only; and the merit of his generalization is now perceived to consist in its addition to—its demerit to consist in its supercession of—the not less grand generalization established by his scarcely-remembered predecessors. This being so, the relationship to one another of the Stahlian and Lavoisierian theories of combustion furnishes an apt illustration of the general truth set forth by a great modern writer, that "in the human mind one-sidedness has always been the rule, and many-sidedness the exception. Hence, even in revolutions of opinion, one part of the truth usually sets while another rises. Even progress, which ought to superadd, for the most part only substitutes one partial and incomplete truth for another; improvement consisting chiefly in this, that the new fragment of truth is more wanted, more adapted to the needs of the time, than that which it displaces."

The partial truth contributed by Lavoisier was indeed more wanted, more adapted to the needs of the time, than the partial truth which it displaced. To him chemists are indebted for their present conception of material *elements;* and especially for their knowledge of the part played by the air in the phenomena of combustion, whereby oxygenated *compounds* are produced. The phlogistians, indeed, were not unaware of the necessity of air to combustion, but, being ignorant of the nature of air, were necessarily ignorant of the functions which it fulfilled. To burn and throw off phlogiston being with them synonymous expressions, the air was conceived to act by somehow or other enabling the combustible to throw its phlogiston off; and a current of air was conceived to promote combustion by enabling the combustible to throw its phlogiston off more easily. Moreover, contact of air was not essential to combustion, provided there was present instead some substance, such as nitre, which, equally with or even more effectively than air, could enable the combustible to discharge itself of phlogiston. But, while the phlogistians, on the one hand, were unaware that the burnt product differed from the original combustible otherwise than as ice differs from water, by loss of energy, Lavoisier, on the other hand, disregarded the notion of energy, and showed that the burnt product included not only the stuff of the combustible, but also the stuff of the oxygen it had absorbed in the burning. But, as well observed by Dr. Crum-Brown, we now know "that no compound contains the substances from which it was produced, but that it contains them *minus* something. We now know what this something is, and can give it the more appropriate name of potential energy; but there can be no doubt that this is what the chemists of the seventeenth century meant when they spoke of phlogiston."

Accordingly, the phlogistic and antiphlogistic views are in reality complementary and not, as suggested by their names and usually maintained, antagonistic to one another. It has been said, for example, that, according to Stahl, the product of combustion is simple, and the combustible a compound of the product with imaginary phlogiston—which is false; whereas, according to Lavoisier, the combustible is simple, and the product a compound of the combustible with actual oxygen—which is true. But in this case, as in so many others, everything turns upon the use of the same word in a different sense at different periods of time. When Lavoisier spoke of red lead as being metallic lead combined with oxygen, he meant that the matter or stuff of the red lead consisted of the matter or stuff of lead *plus* the matter or stuff of oxygen. But, when the Stahlians spoke of metallic lead being burnt lead combined with phlogiston, they had the same sort of idea of combination in this instance as others have expressed by saying that the weight of a body is compounded of its matter and its gravity; or that steam is a compound of water and heat; or, to use a yet more Lavoisierian expression, that oxygen gas itself is a compound of the basis of oxygen with caloric. It is not, then, that the one statement, Stahlian or Lavoisierian, is false and the other true, but that both of them are distorted, because incomplete. Chemists nowadays are both Stahlian and Lavoisierian in their notions, or have regard both to energy and matter. But Lavoisierian ideas still interfere very little with our use of the Stahlian language. While we acknowledge that in the act of burning the combustible and the oxygen take equal part, just as in the act of falling the weight and the earth take equal part, yet in our common language we alike disregard the abundant atmosphere and abundant earth as being necessarily understood, and speak only of the energy of the combustible and of the weight, which burn and fall respectively. Whatever may be the fault of language, however, chemists do not omit to superpose the Lavoisierian on the Stahlian notion. They recognize fully that it is by the union of the combustible with oxygen that phlogiston is dissipated in the form of heat; and, further, that phlogiston can only be restored to the burnt combustible on condition of separating the combustible from the oxygen with which it has united, just as energy of position can only be restored to a fallen weight on condition of separating it to a distance from the surface on which it has fallen.

That Stahl and his followers regarded phlogiston as a material substance, if they did so regard it, should interfere no more with our recognition of the merit due to their doctrine, than the circumstance of Black and Lavoisier regarding caloric as a material substance, if they did so regard it, should interfere with our recognition of the merit due to the doctrine of latent heat. But, though defining phlogiston as the principle or matter of fire, it is not at all clear that the phlogistians considered this matter of fire as constituting a real body or ponderable substance; but rather that they thought and spoke of it as many philosophers nowadays think and speak of the electric fluid and luminiferous ether. The nondescript character, properly ascribable to phlogiston, is indicated by the following quotation taken from Macquer's "Élémens de Chymie Théorique" (1749). It must not, of course, be forgotten that the popular impression as to phlogiston having been conceived by its advocates as a material substance having a negative weight or levity, is erroneous, and is based on an innovation that was introduced during the struggling decadence of the phlogistic theory, and advocated more particularly by Lavoisier's subsequent colleague, Guyton de Morveau, in his "Dissertation sur le Phlogistique, considéré comme Corps grave, et par Rapport aux Changemens de Pesanteur qu'il produit dans les Corps auxquels il est uni" (1762). Macquer writes as follows:

> "'Matter of the sun, or of light,' 'phlogiston,' 'fire,' 'sulphur-principle,' 'inflammable matter'—such are the names usually employed to designate the element fire. But no precise distinction appears to have been drawn between fire viewed as a principle in the composition of a body, and fire when it stands

alone and in its natural state. Viewed under the latter aspect, the terms 'fire,' 'matter of the sun, of light, and of heat,' are specially appropriate to it. Under such conditions, it is a substance which may be regarded as made up of infinitesimal particles, agitated by a very rapid and continuous motion, and hence essentially fluid. This substance, of which the sun is, as it were, the general reservoir, is emanating thence constantly, and is universally distributed throughout all bodies known to us, though not as a principle, or as essential to their constitution, inasmuch as we may deprive them of it—at least in great measure—without their suffering the least decomposition in consequence. . . . Yet the phenomena presented by inflammable substances in burning show that they really contain the matter of fire as one of their principles. . . . Let us, therefore, investigate the properties of this fire which has become fixed, and entered as a principle into bodies. To it we will specially assign the name of 'inflammable matter,' 'sulphur-principle,' and 'phlogiston,' to distinguish it from pure fire."

Again, much the same thing is to be found in Baumé's "Manuel de Chymie" (1765); as, for example:

"We consider fire in two different states: when it is pure, isolated, and forming no part of any compound . . . . when it is combined with other substances, forming one of the constituent principles of compound bodies. . . . We have no certainty whether or not fire possesses weight. There are experiments *pro* and *contra*. . . . During the combustion of substances, combined fire is reduced to elementary fire, and is dissipated as the process goes on. The famous Boerhaave, however, is not of this opinion; he says that, were this the case, the amount of elementary fire in Nature must increase *ad infinitum*. . . . But it is easy to reply to this objection by saying that, as we have the right to presume, the elementary fire discharged from bodies combines with other substances, and that it loses all its properties as free fire on becoming a constituent principle of bodies into the composition of which it enters. . . . The principle here spoken of is that to which Stahl has given the name of phlogiston."

In interpreting the above and other phlogistic writings by the light of modern doctrine, it is not meant to attribute to their several authors the precise notion of energy that now prevails. It is contended only that the phlogistians had, in their time, possession of a real truth in Nature which, altogether lost sight of in the intermediate period, has since crystallized out in a definite form. "I trust," said Becher, "that I have got hold of my pitcher by the right handle." And what he and his followers got hold of and retained so tenaciously, though it may be shiftingly and ignorantly, we now hold to knowingly, definitely, and quantitatively, as part and parcel of the grandest generalization in science that has ever yet been established.

# MYRIAPODS.

By MAJOR HOLLAND, R. M. L. I.

"PLEASE, sir, here's one of them nasty mischiefull many-legs as I told you pisened the melon-bed so as we never got nothink off of 'em. Nobody can't say as they wasn't took care of, for I was a waterin' and a waterin' on 'em mornin', noon, and night, all along the droughty summer. It stands reasonable like to natur' as *water*-melons should take a sight o' water; 'twasn't my overdoin' on 'em with m'isture as rotted the roots off; 'twas these here plaguey varmint!"

Having delivered this oration, and proved to his own entire satisfaction "as how he was right all along, and master was mistook" about poor *Curcurbita citrullus* having been drenched to death with icy pump-water, the obstinate old gardener deposited his writhing scape-goat on the study-table, and retired triumphant to the coach-house, where he whistled loud pæans of victory to the Bramahs and Cochins of the stable-yard.

What yellow-brown *Myriapod* is this? His flexible body, which he is tying into all manner of knots, is composed of no fewer than eighty-one distinct segments, to say nothing of the odd one at the end of the tail, and the five which have coalesced to form the head. If we count these five fused segments as one (as we do the four which Prof. Huxley tells us combine together to make up our own human brain-boxes), then his body is made up of eighty-three somites, of which the cephalic, the anterior-thoracic, which bears that terrible pair of hooked maxillipedes, and the anal, are the only three presenting any marked differences from each other, and from the eighty others which are as "strictly uniform" as the helmets of the metropolitan police.

How the fellow shuns the light! Does his conscience trouble him? Does he feel himself guilty of "pisenin'" the melons, that he wriggles so uneasily until he succeeds in burying himself out of sight in the silk tassel of the pen-wiper? A burrowing troglodyte by nature, I suspect, and on closer examination he proves to be such—*Geophilus subterraneus* (underground earth-lover), of the family *Geophilidæ*, of the subdivision *Chilopoda* (foot-feeders), of the order *Myriapoda*, of the class *Articulata*, according to Newport.

He has no eyes; he doesn't want any; he passes his life in the dark, underground, tearing up old shreds of farmyard manure and vegetable matter, always preferring scavengers' work when he can get it, and doing good service by eating up the helpless, soft, succulent larvæ of the hosts of insects that prey upon our crops. The sins of the wire-worm have been laid to his charge; his third cousins the *Iulidæ* do undoubtedly steal our potato "sets," and bore into young peas, or rather into old peas just "spritting" and about to send up young ones; but it seems doubtful if he himself ever attacks fresh or living vegetables; he seems to be one of Nature's many *vidangeurs*, and, because he is found minding his business and eating up rottenness, he is accused of producing it. As well might we say that our sewer-men produce typhus and cholera. But he has even been charged with having *caused* the potato-disease! because he was found laboring to remove the affected tubers. Beware, ye brave surgeons who fight with zymotic demons and risk your own lives to lift up stricken humanity, lest ye be arraigned for *producing* all the long catalogue of human ills that figure in our sanitary statistics!

Our captive has no eyes; he has, however, an "ocellus," a mere pigment-speck behind the base of each of his fifteen-jointed antennæ, and he has the smallest possible threadlet of an optic nerve. I suspect he cannot see, in the ordinary sense, but can distinguish between the light with which he has nothing to do, and the darkness in which he feels his way about with his antennæ when doing his duty like a humble vegetarian jackal, or adjutant.

The *Myriapods* have been placed at different times in different classes of the animal kingdom. In one famous system we find them under the head of *Crustacea;* another, in remote times, ranged them with the *Hemiptera* and *Orthoptera* as "insects which only undergo a partial metamorphosis." They have slight affinities with both, and even with the *Annelids;* like the latter, they grow in length by the successive addition of new segments between the penultimate and anal. The lower subdivision, the *Chilognatha*, by the situation of their reproductive orifices, seem to betray *Crustacean* relationships; but we remember that, in the first phase of their development, they displayed three pairs of legs only, like the typical hexapod *insect.* They appear to stand out the strong, well-marked, first link of that long chain which bridges over the mighty gulf which rolls between the creeping worm and the flying insect. The *Myriapod* is the lowest *articulate* animal, the *Annelid* the highest *annulose*—i. e., according to the old scheme of classification, the latter term has recently been used with a widely-extended signification. Ten years ago the subdivision *Chilopoda* consisted of four families, including ninety-four genera; and the lower subdivision, *Chilognatha*, of four families, containing seventy-five genera; a tremendous total of variations of a type; but since then they have been shuffled and cut, and lumped and split, like the German states, till nobody knows which is which.

"An *articulation* complete in all its mechanical appliances is not produced in the animal kingdom below the *Myriapod.* A *joint* is the symbol of organic superiority; it is not an arbitrary symbol; it is a unit in an assemblage of signs which proclaim a newer and higher combination in the arrangements which constitute 'life.' At this limit in the animal series the fluids and the solids of the organism undergo a signal exaltation of standard. The system of the chylaqueous fluid exists no longer in the adult organism, it is present only in the embryonic. It is supplanted by that of the blood proper. Coincidentally with the 'joint' at the frontier of the articulate sub-kingdom there occurs a heart to circulate the blood, fibrine, and with it an order of floating corpuscles more highly organized in the fluids; a wondrous development of the muscular apparatus, striæ in the muscle-cell, a rapid increase in the dimensions of the cephalic ganglia, and in those of the organs of the special senses. It is here in the history of the reproductive system that the diœcious character is first unquestionably assumed. These are noteworthy events in the ascensive march of organic architecture."—(Dr. Williams, *Magazine of Natural History*, 1854.)

The armor-plates of the cylindrical *Iulus* are composed of a semi-crustaceous hard substance, but in the *Scolopendridæ*, which our "false wire-worm" closely approaches, the integuments are of a flexible chitinous substance, the back of each segment is covered by a plate, the ventral surface by a somewhat smaller plate, the epimeral portions, as well as the interspaces between the somites, are covered by a loosely-fitting coriaceous membrane of much thinner texture.

The circulating system has been a battle-ground for men with great reputations. The nervous and reproductive systems, and the development day by day from the ovum, have been drawn out with elaborate minuteness by Newport, in "Philosophical Transactions" for 1841 and 1843, but I have not fallen in with a drawing of their tracheary system, which is well worthy of careful study.

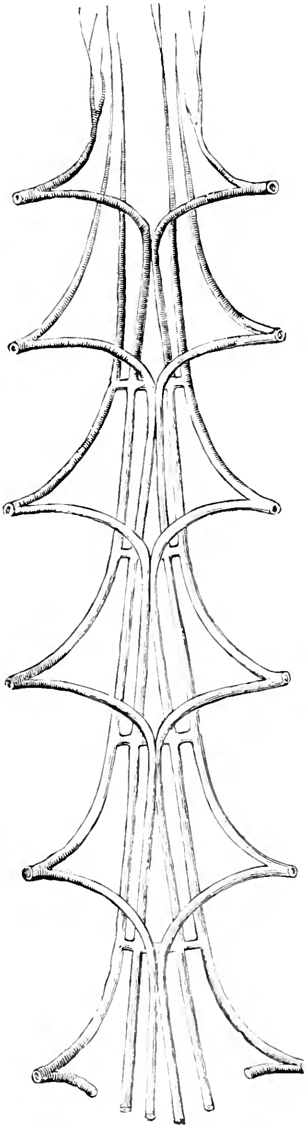
The spiracular orifices are not placed as in insects between the segments, but in the side of each, a little below the dorsal plate; they are not minute apertures, nor vertical slits, neither are they furnished with "guards" of setæ, or hairs, to exclude dust and foreign bodies; but they are circular openings, each with a well-defined, hard-looking ring, over which the tough but pliable lateral membrane passes, lining the entrance, which is directed slightly backward, and can be closed by a sphincter-muscle. The tracheæ are very large in the anterior segments, occupying no small portion of their internal cavities, but they decrease in diameter in proportion as the segments recede from the head; possibly there may be need for a more abundant supply of oxygen in the region of the brain, and in the first-formed portions of the body, than in the equally large but more remote additions which are from time to time developed near the caudal extremity.

Let us detach half a dozen pairs of spiracles, with their tracheal appurtenances complete, from the dissected tail-end of *Geophilus* the much maligned, float them on to a slide, and bring the "two-thirds objective" to bear upon them.

A ladder of shining silver, a very Jacob's ladder, bright and beautiful enough to have been let down from heaven for the feet of angels.

The six uprights and the cross-rungs are all constructed of the same tubular wire rope glistening with a dazzling metallic lustre, and without a flaw anywhere. The tubes are composed of an outer and an inner coat, containing between them the spiral coil, to which they are closely attached; a delicate membrane also connects the turns of the spiral with each other. It is interesting to compare these animal breathing tubes with their analogues *the spiral vessels* of the vegetable kingdom; the latter are easily extracted from the young shoots of asparagus, or from the leaves of the hyacinth. The spring-like coil insures a free open passage for the air which rushes in by the spiracular orifices, expiration being effected by the contraction of these elastic channels, by which the effete air is forcibly expelled through the openings by which it originally entered.

The main tracheæ pass down the axes of the blood-channels, floating in the vital fluid, which they revivify with the oxygen which they thus carry to and through the life-stream. We are told that the air-pipe does not terminate where the wiry-looking spiral comes to an end; the latter dwindles away imperceptibly to nothing, but the trachea thence becomes membranous, and, dividing into innumerable branches, which bear to the main trunks the same relations that the capillaries bear to the arteries, penetrates the substance of the muscles, inconceivably fine branches having been traced accompanying the nerves, while the ultimate plexiform extremes of the system aërate immediately the solids. "In all the transparent structures of insects every observer may prove for himself that the blood-currents travel in the same passages as the tracheæ, but this is only the case with the primary and secondary branches, *never* in the capillary tracheæ; the blood-corpuscles of the *Myriapod* exceed by several times in diameter that of the extreme capillary membranous tracheæ; it is perfectly marvelous to what inconceivable minuteness the air-current is reduced in traveling along these tubes." What a simple and efficient plan, what an economy of space is this arrangement of tube within tube, for aërating the blood in a class



TRACHEÆ OF GEOPHILUS SUBTERRANEUS. Magnified 140 diameters.

of lowly, creeping things of earth that do not attain to the dignity of lungs! There is a saving of time, too, for the blood is made arterial while on its journey, and thus travels direct (without the delay of passing off to special pulmonary organs) to the performance of its functions, removing, replacing, renewing, sustaining, building up, absorbing. Having accomplished these, and become as it were venous, it passes into the intervisceral spaces, and there, receiving an increment of fresh globules, the products of digestion, completes its circuit by returning through distinct valvular openings into the dorsal vessel from which it was first distributed. "Among the *Chilognatha*," says Siebold, "the *Iulidæ* are noticeable for the very simple character of their trachean apparatus; their air-canals neither ramify nor anastomose. With the *Glomerina* the tracheæ are branched, but do not anastomose; but those of the *Chilopoda* are very ramose, and their large trunks intercommunicate at their origin by longitudinal and transverse anastomoses, so that each stigma can introduce air into the entire trachean system." It was chiefly with the view of drawing attention to this last-mentioned fact (a most striking evidence of design), to this remarkable example of the exquisite adaptation of the creature's construction to the condition of existence ordained for it by the Creator, that I began this bit of simple gossip about *Geophilus*. In his subterranean career he constantly meets with accidents which link him up in sympathetic association with Brunel and Stephenson, and the Bedouin of the desert. He never bored a practicable highway beneath the bed of Isis, nor made firm the foundations of an iron road across the quaking surface of Chat Moss; neither has he braved the burning sand-blasts of the simoom; yet in his degree he has met with such like critical experiences a hundred times.

One day the roof of his tunnel crashed in upon him, and buried a dozen of his segments, squeezing the very breath out of them; on another day the rain had saturated the rubbish-heap he was toiling in, a score or two of his somites were under water, and he had to "batten down" the stigmata belonging thereto to save those portions of himself from drowning; and yet, again, in the scorching dog-days, a hot wind swept the earth, and a dry and thirsty clod, crumbling away, discharged an avalanche of dust which overwhelmed nine-tenths of him. In each and all of these catastrophes his life would not have been worth ten seconds' purchase, even with his many spiracles, but for the anastomosing branches of his windpipes, the cross-rungs of his air-ladder, which enabled the air received by the unchoked segments to pass in every direction through the whole system. That there is perfectly free communication from any one spiracle to the whole network of air-passages may be seen by examining the figure which I have given; and if any reader has still a doubt on his mind he may remove it, if he is a dexterous manipulator, by dissecting out the trachcary apparatus of the first *chilopodous Myriapod* he can lay hands on;

and, stopping the orifices of all the spiracles but one, he will find that through that one he may inject the whole labyrinth of air-vessels with carmine.

I observed that a correspondent, J. G. D., in December last, was much surprised at the display of a phosphorescent light by a centipede he had found. *Geophilus electricus*, a member of the same family, and a near relation of our *Subterraneus*, must have been the pyrotechnist he chanced upon. "The caustic brown fluid which most *Myriapoda* when touched emit from a row of orifices, *foramina repugnatoria*, situated on the sides of the segments of the body, and which exhales an odor like that of chlorine, is secreted by small pyriform glandular follicles situated immediately beneath the skin; it is from glands upon the sides of the body analogous to these that *Geophilus electricus* emits a luminous liquid."

It would be most interesting to ponder over the three varieties of breathing apparatus mentioned by Siebold, and to note their special adaptations to the life conditions and necessities of the three distinct genera provided with them; and there are other wonders in the ways and mechanism of each and all of them that one longs to dwell upon; but we are not essayists here, only cheerful "gossips" of the wayside, who seek to be merry and wise, accurate, though simple and amusing. We have run to the end of our tether, and must say good-by to *Geophilus subterraneus* and all the *Myriapods.—Science-Gossip.*

# SOAP-BUBBLES.

By Prof. RÜCKER.

IN the museum of the Louvre, in Paris, there is a vase which has by some strange chance been handed down to us through the long ages which have proved fatal to many others far more worthy of preservation than itself. It was manufactured in Italy—before the foundation of the city of Rome—by the ancient Etruscans, and it is decorated—and this is the reason I bring it to your notice this evening—with a design representing a group of children blowing bubbles. This ancient relic of those early days incontestably proves to us that the art of performing that beautiful experiment, if not with soap and water, at least with some one of the comparatively few liquids with which it can be satisfactorily undertaken, has been known at least for twenty-five hundred years. But, though generation after generation the children amused themselves with it, century after century passed away, leaving unanswered, and in all probability unthought of, the

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[1] A lecture delivered in the Hulme Town-Hall, Manchester, on Wednesday, November 3, 1875.

numerous questions which it cannot fail to suggest to us. Why is it so easy to blow bubbles with some liquids, and so hard to form them with others? Why does a bubble when blown at the end of an open tube gradually contract and disappear? Why, when it bursts, does it not still remain a liquid film, but is shattered to an almost imperceptible dust? These and a hundred others remained unanswered, and, as I have said, perhaps un-put, until after the genius of Newton had attacked the far more difficult problem of the colors which bubbles display. To night, however, I hope to be able to give you the answers to some of these so long-delayed inquiries, as it is now perhaps two hundred years since men of science began to turn their attention to the phenomena of liquid bubbles, and of those properties of liquids on which they depend, and their efforts have been rewarded with no small measure of success, although it is certainly only within the time of many of us here that they have been able to give anything like a complete explanation of them all. In order, however, that we may understand how best to study the laws and constitution of a soap-bubble, it is necessary that we should in the first place clearly comprehend what it really is. We all know how soap-bubbles are ordinarily formed. A common tobacco-pipe is dipped into a mixture of soap and water, and when it is withdrawn a thin liquid film stretches across the mouth, which we can blow out into a bubble, and then shake off and detach from the tube. I will now perform the experiment of blowing a bubble before you; only, instead of employing a tobacco-pipe, I will use this glass funnel, and for the common soap and water I will substitute a mixture of Castile soap, water, and glycerine. [A large bubble was speedily blown, and it showed the usual beautiful colors. This and the succeeding experiments were dexterously and successfully performed, and were much applauded].

You now see how, by using a proper liquid, and by taking proper precautions, we are able to obtain bubbles of enormous size. But I wish you for a moment to confine your attention to the bubble, not in its full-blown beauty, as you saw it just now, but rather in that stage in which it was merely a thin film covering the mouth of the funnel. Now, this film was originally the topmost layer of that portion of the liquid inclosed by the funnel, which as I withdrew it skimmed off a thin slice from the surface—a slice so thin that had I allowed it to drain for a while its thickness would not have exceeded four millionths of an inch. But, although the total quantity of liquid contained in it was so small, the surface of the film was no less than twice the area of the orifice of this large funnel. Hence, both from the method of formation of the film and from its constitution when formed, it is evident that, if, in any respects, the surface of a liquid differs from the internal mass, if there are laws which govern and forces which are at play on the surface, the effects of which we do not recognize elsewhere, these peculiar properties must be to us of primary importance, if we would understand the theory and constitution of a soap-bubble. The course which I shall adopt this evening is, in the first place, to study the laws and forces which are in operation on the surface of a liquid, and after that I shall try to show you how they may be used to explain the phenomena which we observe in the short but brilliant life of a bubble.

I have upon the wall a diagram on which three of the principal properties of the surface of a liquid are enunciated. That to which I wish first to draw your attention is that the surface of a liquid is in a state of tension. It is necessary that before we go any further you should have a clear comprehension of the meaning of this word "tension." I have here a piece of India-rubber, and if I stretch it with my hands I throw the whole of it into a state of tension. The peculiarity of this state is that, if I were to divide the India-rubber into two portions with a sharp knife, the parts, no matter where the incision was made, would instantly fly in opposite directions, and each would become shorter. But what each of those parts would then actually do—that is, contract or become shorter—each is now tending to do; but, since it could only become shorter by elongating the other part, and as that is pulling in an opposite direction with equal force, the two forces neutralize one another, and the whole remains in a state of rest, and also in a state of tension. If, then, we generalize from this particular instance, we may define a state of tension as follows: that a body is said to be in a state of tension when each of any two parts into which it may be divided tends to contract and to expand the other. You observe, then, that the tendency of one part to extend the other is the criterion of a state of tension; and I will now show you a couple of experiments which will, I think, enable me to prove that it exists in the surface of a liquid.

I have here a small iron ring, and stretched loosely across it, from side to side, there is a piece of cotton. I dip it into a vessel containing some of the soap-mixture I used just now, and it comes out with a film adhering to it precisely in the same way as the funnel did. I now show you upon the screen the image of the ring, with the thread stretching across it, and resting upon the thin liquid film. If what I have just been saying be true—if each portion of the film be in a state of tension—then each of the parts into which the thread divides it is tending to contract and to expand the other. Thus, the thread is acted upon by two forces: the portion of the film to the right is tending to pull it to the right, and the portion on the left is tending to pull it to the left; but, inasmuch as these two tendencies are equal and opposite, the effect upon the thread is as if they did not exist; that is to say, it will remain at rest in any position on the film. I will now move the thread about on the film with a wire, showing that it will remain wherever I place it. I distort it and put it in any position I like. Let us, however, consider what will happen if I break the film upon one side of the thread, and leave it uninjured upon the other. The surface-tension, destroyed upon one side, will remain in action in the unruptured film, and therefore we should expect the thread to be pulled toward the uninjured side. We can easily put the matter to the test of experiment. I break one side by touching it with a hot wire, and what we foresaw occurs, the thread is instantly pulled toward the side which the wire did not tear. This experiment proves that the surface of a liquid is in a state of tension. I have, however, another experiment to show you upon the same point, which will add to our knowledge upon the subject, for it will not only show that the tension exists on the surface, but that in different liquids it exists in different degrees of intensity. You now see upon the screen the image of a few drops of colored water, which are placed upon a glass plate. I dip a glass rod into some pure water, and touch the colored film with the drop which adheres to the end. As you see, nothing very particular happens. There is only a slight diminution of the blueness in the centre, owing to the fact that the colored water has been mixed with the pure water. Now, I will dip the rod into alcohol, and you will see a different result. As soon as I touch the blue water with the alcohol a motion occurs, and it moves rapidly away from the point at which the contact took place. Now, let us consider shortly what the explanation of this phenomenon is. The surface of the water and the surface of the alcohol are alike in a state of tension; but the tension of the surface of the water is greater than that at the surface of the alcohol. At the moment I put the drop of alcohol upon the water we had a small drop of alcohol surrounded by a large quantity of water, and between the two there was a line of demarkation, which we may, for simplicity's sake, liken to the thread you saw just now. When I destroyed the force of the tension in the first experiment on the one side, the force which remained on the other side pulled the thread toward it. In this case the force was acting on both sides; but the force at the surface of the water pulling away from the centre of the alcohol-drop was greater than the force at the surface of the alcohol-drop pulling toward its centre. The consequence was, that we obtained a motion in the direction in which the greater force was acting—that is, in the direction in which the water was pulling away from the centre; and this continued—the water and alcohol moving farther and farther away, until the two became entirely mixed together. An experiment similar to this may be performed after dinner in the evening: When we pour some wine into a glass we generally in doing so wet the sides, and the result is, a thin film of liquid adheres to them above that portion of the glass which is filled with wine. This film soon contracts into drops, and each of these drops consists, as all wine does, of a mixture of water, alcohol, and certain other substances, the presence of which we may for the moment neglect. Alcohol, as you know, is an extremely volatile fluid, which evaporates very rapidly, and therefore above the surface of the liquid there is a small atmosphere of alcohol formed by evaporation from the wine. This evaporation goes on in the drops as well as in the main body of the wine, but more rapidly at the upper surface of a drop than at the lower; the reason being that the lower part is more completely immersed in the little cloud of alcohol which hangs over the wine itself. A drop is thus formed composed in the upper part of water, with comparatively little alcohol, and in the lower part of water with a larger proportion of alcohol. The experiment I have just shown proves that the tension in the upper part must be greater than that in the more alcoholic or lower portion of the drop. Hence you may often see drops of wine actually running up the side of a glass, in obedience to a force exerted in an upward direction, by the greater surface-tension of the portion containing the larger percentage of water. A very important deduction may be made from the fact that the surface of a liquid is in a state of tension. You saw in the first experiment that, as soon as the film on the one side of the thread was broken, that on the other side contracted very rapidly, and took up a form with as small a surface as was possible under the circumstances. If we were to generalize from this particular instance, we should be led to the conclusion that, because the surface of a liquid is in a state of tension, and thus each part of it is tending to contract, therefore it will always assume a shape which will have the smallest possible surface. I will now show an experiment to illustrate this fact. I have here a tube formed of four plane pieces of glass, through which I shall be able to send light, and so show you the image of its contents on the screen. It forms, in fact, a little box of glass, the ends of which are open, one of them being considerably narrower than the other. I now put the larger end of this tube into a mixture of soap and water, and I withdraw it with a film adhering to it. This film has a tendency to assume that shape which has the smallest possible surface; and evidently, by moving up the tube toward the narrow end, its surface can be made smaller than it is at present. You now see on the screen an image of the tube. I move it for a moment in order to form the film. You now see the image of the film, and I think you will observe that it is slowly moving up the tube, and therefore that its surface is becoming smaller and smaller. The experiment might be prolonged until the film burst; but, at all events, you have there sufficient proof that it moves into a position in which its surface is diminished. And, further, inasmuch as the image of the tube is turned upside down on the screen, what appeared to you to be a motion from above to below was, in fact, a motion from below to above; the film was in reality moving upward, although to you it appeared to be moving down. It was really raising its own weight instead of being pulled down by it. We have thus now established this quality of liquids, namely, that their surfaces tend to become as small as possible, and we may extend the law to another and very interesting case.

Let me suppose for a moment that I take a mass of clay: it is evident that I could mould it into an infinite number of different forms; each of these forms might have precisely the same volume, might occupy exactly the same space, but they might all have very different surfaces. For instance, if I took a rolling-pin and rolled the clay out into a thin disk, and then compressed it into a round ball, it is evident that, although the volume might be precisely the same in the two cases, the area of the surface would be much greater in the disk than in the ball. Now, in the experiment I showed you last, the film moved up the tube, because it had a tendency to diminish its surface as far as possible; but, if I had continued the experiment longer—if I had allowed the film to move up to the narrowest part of the tube, it would, even then, only in part have satisfied this tendency, and not have done so completely—it would have attained the smallest surface possible under the circumstances, though not the smallest possible surface. The reason why it would not have done so is this: that forces were acting upon it other than that which tended to make it contract, for it was also affected by the force of adhesion to the sides of the glass tube; and, as a matter of fact, liquids are ordinarily subjected to the action of no less than three distinct sets of forces. The first of these is the attractive influence of the earth, or the weight of the liquid; the second is the adhesion of the liquid to the sides of any solid vessel in which it may be contained; and the third class comprises those forces which are at play in the liquid itself. It is evident, then, that the form which a liquid takes will not be due to any one of these, but to all three. The form which it would assume if left to the action of its molecular forces will be modified in the first place by its weight, and in the next by the adhesion to the sides of the solid vessel. Hence the question arises, if we take a liquid free from both these disturbing forces—free from the attractive influence of the earth, or practically so, and free also from the force of adhesion to the side of the solid vessel—which of all the possible shapes into which I might mould my mass of clay would the liquid assume so as to have the smallest possible surface? This question we are able to answer very easily by means of experiment, and the method by which we do so depends upon the application of an extremely simple principle. When we place a stone in a mass of water we have, in order to immerse it entirely, to push aside, to remove to the right and left, a certain quantity of water, the volume of which is precisely equal to the volume of the stone; and the stone sinks to the bottom, because its own weight is greater than the weight of the water which it has so displaced. A piece of cork, on the other hand, would rise to the surface, because its weight is less than the weight of the water equal in volume to itself.

If we could obtain a body the weight of which was precisely the same as the weight of the water it displaced, it would have no tendency to sink or swim, but would remain at rest in any part of the water into which we might choose to place it. Hence this body would be practically free from the attractive influence of the earth, and we should have succeeded in neutralizing the force of gravity, since a body having no tendency to rise or fall might be considered as removed to such a distance from the earth as to have no weight. Of course, this conclusion is independent of the fact whether the body introduced into the water is a liquid or a solid, and we may substitute for the water any other liquid; but, if we employ two liquids, they must satisfy the following conditions: In the first place, they must not mix together, as wine and water do, but must remain separate, like water and oil. In the second place, the weight of any volume of one must be exactly equal to that of the same volume of the other; and, in the third place, the two liquids must have, when in contact, no chemical effect upon each other. Could two such liquids be found, a small quantity of the one introduced into a mass of the second would be a state eminently favorable for determining the shape which it would assume under the influence of its surface-tension alone. It would, as I have pointed out, be free from the attraction of the earth, and it would also be free from the force of adhesion to the sides of a solid vessel. It would, however, be extremely difficult to find two liquids which would satisfy these conditions; but, although we cannot find them to our hand, we are able to manufacture them. Water is a liquid which is heavier than oil, and alcohol is on the other hand lighter than oil; and, if we mingle water and alcohol, we may make a mixture, the weight of any given volume of which is precisely equal to that of the same volume of oil, and by introducing a few drops of oil into the mass of alcohol and water of the right density we ought to succeed in observing the form which a liquid assumes under the influence of its surface-tension alone. You now see upon the screen the image of a mass of oil in a mixture of alcohol and water of the kind I have just described; and you see that our question is at once answered—the oil assumes a spherical form. From this we learn that a liquid, if left to the action of its surface-forces alone, will become a sphere. But inasmuch as the effect of the attractive influence of the earth, or the weight of the liquid, increases with the quantity we use, while on the other hand the surface-tension, or its own moulding molecular force, remains precisely the same, we should, if we use a large quantity of liquid, expect the weight to be the particular force which determined its shape; and if we employ a small mass of liquid, then the surface-tension, growing proportionately greater, would become the more important. Thus it follows that, although we have to use the most accurate adjustment in order to obtain a sphere of oil an inch in diameter, every rain-drop, every dew-drop, and every soap-bubble, is in itself almost a mathematically accurate sphere. It is very possible, of course, to make a liquid assume any number of other shapes you please, but I wish now to draw your attention to the fact that we are able to give it another very simple form, namely, that of a cylinder: and I will show you upon the screen the conversion of a spherical soap-bubble into a cylinder. You now see the image of a glass funnel. I take another of precisely the same dimensions, and blow upon it a small bubble, which I make adhere to the first, and then I draw it out into a very accurate cylinder. This proves that the form of a quantity of liquid may, under proper conditions, be cylindrical; but if we make the cylinder of such dimensions that the length is very considerable in proportion to the breadth, then the liquid will only retain the cylindrical form for a very short time indeed. The slightest jar or disturbance of any kind will of course make it deviate from its shape, and that deviation when once begun is continued, as it were, by the liquid of its own accord. The series of transformations through which the cylinder will go, I have represented for you in the diagram. At the top is the long cylinder, which represents the liquid in its first state. Assuming that it is slightly disturbed, you see that it swells out in some places and contracts in others; and the elevations and depressions grow greater and greater, until the mass of the liquid becomes, as in the lower figures, little more than a series of balls tied together by very fine liquid threads. The transformation does not end here; the threads are soon broken, and thus what was originally a continuous cylinder is transformed into a series of alternately large and small spheres. I shall have to make use of this particular transformation of the cylinder later in my lecture; but I wish for the moment to call attention to the fact that one very interesting instance of it is observed whenever water flows out from the bottom of a vessel through a small circular hole. In such a case the form of the column of water would be approximately that of a long cylinder. But, as I have already pointed out, this is a state of what is called unstable equilibrium—of equilibrium which may exist for an instant, but not for a longer time. Hence the above series of transformations are gone through. We have alternately contraction and elevation; these go on until at length the falling column of water is broken up into a falling column of drops.

We must now, however, pass on to another property of the surfaces of liquids, namely, that they press on the liquid, or air which they contain, in much the same way as a blown-out bladder presses on the air within it. I will show you an experiment illustrating this in the following way: If a bubble presses on the air within, then it is evident that, if we made a hole in its side, the tendency of the compressed air would be immediately to escape through the hole, and we should have a current of air flowing out of the bubble, which would thus become smaller. I will blow a bubble at one end of a glass tube, and leave the tube open at the other end; we shall thus have a small hole formed in one side of the bubble, which, if our theory is correct, will gradually contract and disappear. You now see on the screen images of the ends of two tubes. I have the power of cutting off one tube entirely from access to the other; and I do so now, so that you will, if you please, consider for the purposes of this experiment that tube only as existing at the extremity of which I shall blow the bubble. You now see the image of the soap-bubble, which as long as the tube is closed remains unaltered in size; I open it, and it now at once contracts and disappears. This, then, conclusively proves that the air in the bubble was compressed. I will now go a step farther, and show that the amount of this compression depends on the size of the bubble. If it be large, the air is not so much compressed as if it be small. Let us consider what would happen if I formed bubbles at the two ends of a tube. If they were of the same size, evidently—the one pressing the air in one direction, and the other pressing it in the other with equal force—no effect would follow. If, however, one bubble were smaller than the other, and what I have said be true, the small one would compress the air within it, and drive it from left to right (say) with greater force than the other would tend to drive it from right to left; hence the air would flow from the small bubble to the large one; the large one would increase, and the small one diminish. The smaller the bubble, the more the air would be compressed; and thus the current would become greater and greater, until at last we should see the small bubble entirely disappear, the large one having absorbed all the air which it previously contained. I will try to show you this on the screen; first disconnecting the two tubes, I blow at their ends bubbles of unequal size. I will now place them in communication, so that the air can pass from the one to the other. You see, the small bubble contracts and the large one expands, and we thus learn that the pressure of the smaller or more curved bubble upon the air is greater than that of the less curved one.

I now come to the third property of liquids of which I wish to speak; and that is, that the surface of a liquid is generally either more or less viscous than the interior. With reference to the word viscous, you will find a familiar example of two liquids which differ very much in this property of viscosity in treacle and water. Take a vessel of treacle and a vessel of water, pour the liquids out, and note the different way in which they behave; the water flows out smoothly, one part slipping over another, whereas the treacle comes out in a great rolling mass, which seems to stick to the sides of the vessel. Again, put a spoon into a vessel of water, and move it through the liquid, you will find little resistance to its motion, the water seems to flow away to make room for it and closes in again immediately behind. Try the same experiment with the treacle and you will find the resistance very much increased; in front of the spoon a little heap of liquid gathers, which subsides but slowly, and there is a depression behind which is as slowly filled up. It is evident that there is some difference between the interior constitutions of the treacle and the water; and that difference consists in this, that the particles of which the treacle is composed move among themselves with very much less facility than do those of the water. The fact, then, of one part of a liquid moving more or less easily among the other parts is that which distinguishes one from another in respect to their viscosity. In a very viscous body, like treacle, the parts move with difficulty; and in a non-viscous liquid, like water, they move with comparative ease. The fact which I wish to impress upon you this evening is, not that one kind of liquid differs from another; but that one part of a liquid may differ from another in respect of viscosity; and that as a general rule the surface is more or less viscous than the interior. I will now show you an experiment which will illustrate this fact in a very striking way. I have in a glass vessel a little magnet, which, when I bring near to it a large magnet, will easily and readily follow its motions. The vessel also contains a mixture of water and a substance called saponine. This saponine is extracted from the horse-chestnut, and is, as far as I know, chiefly interesting on account of the extraordinary effect it produces on water when mixed with it. In making the mixture, I have added only one part of saponine to sixty of water, and, to look at, it retains the properties of water; it is colorless; it has none of the viscosity of treacle. In fact, the saponine has next to no effect on the interior parts of the water, but it has a most extraordinary and marked effect on the surface; and that I will now try to illustrate. You now see upon the screen the image of the magnet, and the vessel at the bottom of which there is the mixture of saponine and water. The magnet is at present about an eighth of an inch above the liquid. I bring near the large magnet, and you see how easily it follows its motions. I will now pour in some of my mixture until the magnet lies upon the surface, and I then again bring the large magnet near it. It is now upon the surface of the mixture, and you can see some of the bubbles formed as I pour the liquid in. I bring the large magnet as near as it was at first and am moving it, but it produces no effect. I bring it nearer and nearer—still no effect. I bring it so near that you can see its shadow, and still the magnet remains absolutely motionless. On the surface of the liquid, then, we have found that the little magnet is totally insensible to the attractive force of this large one. You may say that the same would happen in the case of glycerine or treacle. It might; but now comes the extraordinary part of the experiment. I pour in some more saponine and water, until the little magnet lies a quarter of an inch below its surface; I then bring the large magnet near, and you see the result.

It moves almost as freely as in the air itself. Hence we have a most convincing proof that the surface-viscosity of this solution is very much greater than the viscosity of the interior of liquid; and that the resistance offered to motion by the surface is many times larger than that experienced by moving bodies in the interior.

Another experiment will illustrate this enormous surface-viscosity of the mixture of saponine and water in a still more striking way. I have already explained to you that if we blow a bubble at the end of an open tube, the bubble will gradually contract until all the air is expelled. What, however, will occur if, instead of simply allowing the bubble to drive the air out, I suck the end of the tube and draw it out more quickly? I will first perform the experiment on some of the soap and water I have used before, and you will see that, although the bubble will contract more rapidly than before, it will retain throughout the whole of the experiment its spherical form. I will now repeat the same experiment with saponine and water. In this case, on account of the great viscosity of this thin film it will be unable to follow the retreating air as quickly as it must do to retain its spherical form; the consequence is, it will be unable to retain that form, and it will therefore collapse and wrinkle up into a purse-shaped bag.

I hope I have succeeded in proving to you that these three properties of liquid surfaces exist. I must now go on to explain how they can be applied to the theory of soap-bubbles. Let us suppose, in the first place, that a bubble is rising in a vessel of water. It will tend to assume a spherical form; but as it rises to the surface it will be flattened in the direction in which it is moving, and, instead of being a perfect sphere, it will be longer in one direction than the other. Evidently, as it moves, it has to displace the water in front of it, which flows away to the right and left out of the way of the bubble. But, as I have explained, all liquids offer a certain amount of resistance to the motion of one part upon another; and, although the resistance offered by water is extremely small, it must be taken into consideration. The liquid, therefore, has to flow out of the way of the advancing bubble, and to overcome the resistance offered to its motion; but as the bubble rises nearer to the surface it moves faster and faster, and therefore the water must be removed from its path more and more quickly. But the resistance offered to its motion becomes greater the faster it moves; hence you have the bubble rising more quickly, the water being obliged to get more quickly out of the way, and finding more and more difficulty in doing so, and having, when the bubble gets very near the surface, less space between the bubble and the surface to flow away in. The result is, that the water cannot get out of the way, and therefore the bubble carries it up with it and forms a thin liquid film, which we see as foam upon the surface, through which the bubbles of air are rising. Supposing the bubble thus formed were placed upon a solid plate, it would have the form of half a sphere; and, as the bubble compresses the air in it, the air would press upon the plate; but the plate would be able to resist the pressure, and the bubble would remain a hemisphere with a flat base. If, on the other hand, the bubble were formed on the surface of a liquid, there would be precisely the same pressure on the bottom, only it would be acting on a medium which would give way to it; the liquid, therefore, would yield to the pressure of the air, and we should have the bubble as it were a little buried in the liquid by its own pressure. As the pressure increases with the smallness of the bubble, we should expect a small bubble to be very deeply buried, and a large bubble to be slightly buried. I will now pour into the cell, the image of which you see, a small quantity of liquid, and blow in it a very small bubble. You now see the images of two bubbles which have risen to the surface, and that they are very much buried in the liquid by virtue of their pressure. I will now blow a large bubble. You see that within it the surface of the liquid is very much less depressed. I will blow a still larger one. Now I have succeeded in blowing a very large bubble, and the lower part of it is not appreciably depressed. I will now blow a great number of bubbles in contact, and will then point out one or two facts. You now see that odd network which represents a great number of bubbles. There are two points I wish you to notice. In the first place, when two bubbles meet, the surface between them may be either plane or curved. It is plane if both bubbles are of equal size, and therefore compress the air within them with equal force; but, if they are unequal, the smaller bubble, compressing the air more strongly, indents the larger, and the surface which divides them is curved. Notice also another very curious point, namely, that in no case do more than three bubbles meet in a point, excepting for an instant. This follows from the law that a large number of bubbles, as well as each one, will assume the smallest possible surface. I cannot go into the proof of this, but it follows from the law I have already given you. As the bubbles form, collapse, and disappear, you see that they always so arrange themselves that no more than three shall ever meet in a point.

Now, then, we have got our bubble on the surface of the liquid. Let us consider what will happen to it after that. Evidently the liquid of which it is composed will run down the sides by virtue of its own weight; but there will be a certain resistance to this motion, greater or less as the viscosity of the surface is great or small. Hence, there are two different dangers which may beset the bubble. The first of these is, that when the surface-viscosity is small, then the liquid runs down the sides of the bubble very easily; the consequence is, the bubble becomes very thin and bursts. There is, however, an opposite danger which may imperil the bubble when the surface-viscosity is great; and that is, that the liquid does not flow down in a straight line or regular curve, but in irregular masses, which every now and then tear away from each other. Now, these ruptures make little holes in the surface of the liquid; and when a hole is made the surface-tension tends to tear the liquid away, and to make it bigger. If the liquid has a very considerable surface-tension, the small holes in the surface may be so instantly turned into large ones that the bubble may burst. This is, however, less likely to occur when the surface-viscosity is small than when it is great, because in that case the liquid flowing in from all sides can more easily fill up the hole, and restore the damage done, before it becomes dangerously large. The best kind of bubble for lasting is one in which the surface-viscosity is tolerably large, so that the sides of the bubble may not become thin too quickly, and in which the surface-tension is not too great, so that any small fractures which occur may not be instantly enlarged. When we find a liquid which has these two properties, we have all the requisites for making good bubbles; but sooner or later a hole is made, and then the bubble bursts, and in a way which is probably very different from what, *a priori*, we should expect. In the first place, the orifice which has been formed becomes rapidly larger, the surface-tension which acts all round its edges and pulls the film away from its centre tending to enlarge it. Secondly, the surface of the liquid is necessarily very much curved all round the hole, and a greater pressure is therefore excited at that part by the surface on the liquid which forms the interior of the film than elsewhere. Hence the liquid becomes heaped up around the hole into a ring which is thicker than the rest of the bubble, though its thickness is very small compared with the diameter of the hole. The liquid in the ring is thus in circumstances somewhat similar to that in the long cylinder we have already studied—it undergoes a similar series of transformations and is broken up into drops which are flung away from the bubble. Another ring is instantly formed and as instantly broken, and the process is repeated again and again with inconceivable rapidity, until in a very small fraction of a second a little cloud, composed of the numerous minute drops which have been formed, is all that remains of the bubble.

I must now draw to a close. I have discussed with you, as well as I could in the short space of time allotted to me, the history of a bubble from its birth, in the bosom of the liquid, to its dissolution in the air above. The facts and experiments I have brought to your notice have been, I hope, in themselves sufficient to attract you; but I think they will acquire an additional interest if, before we part, I tell you something about the man to whom we owe most of our knowledge on the subject of my lecture. I mean M. Plateau, the Professor of Physics in the Belgian University of Ghent. This gentleman began his studies on liquids when a young man, and was already well known for his success in scientific investigation, when a misfortune overtook him which one would have thought would have put an end to his further researches. He became hopelessly blind. A misfortune like this would have crushed a weaker man; but in the case of M. Plateau it served to show the genuine metal he was made of. He spent the long hours of darkness, not in useless repining, or vain regrets, but in endeavoring to advance the knowledge of his race by pondering over the unsolved problems connected with the subjects he understood so well, and in devising experiments, often of the most exquisite ingenuity, for putting his theories and conclusions to the test. These, which he could no longer perform for himself, were undertaken for him by a devoted band of friends, among whom was his own son; and the result has been, not merely a very large addition to our knowledge of the properties of the surfaces of liquids, but, what is perhaps far more important, the presentation to the world of a spectacle of victory over almost overwhelming obstacles such as it has seldom seen. It is not well that our knowledge of scientific facts should be entirely divorced from an acquaintance with the lives and labors of their discoverers, or that we should come to regard them simply as a sort of revelation made to a fortunate few, to the rich inheritance of which we have been lucky enough to succeed. The men who built up the pile of modern science were not of those who sit still and wait with folded hands for some inspiration, they know not whence; rather they performed their tasks, and won success amid difficulties and discouragements to which we in happier times are strangers. But, while rightly ready to pay our homage to the great achievements of the past, we should ever be watchful to honor duly deeds which will cast a lustre upon our own time;.and among these the life-work of M. Plateau holds in some respects a position second to none. Others may deserve a higher place for the number, or practical or scientific importance, of their discoveries, but none have more honestly earned the praise due to those who have done what they could; and the world, which is so apt to appropriate the work and forget the worker, should be taught at all events to remember this, that we owe some of the most charming experiments in the whole range of physics to one who himself has never beheld many of them, and of whom, with respect to the rest, we must in all sadness say, he " shall see them again no more forever."

# THE EVOLUTION OF HEBREW RELIGION.

By FELIX ADLER,

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"Dans l'opinion du peuple pour qui ces livres ont été écrits le point capital et essentiel n'est certes pas la narration historique, mais bien la législation et l'édification religieuse."[1]

IN 1795, Frederick Augustus Wolf published a modest octavo volume entitled "Prolegomena to Homer," from whose appearance is dated the beginning of a new era of historic criticism. The composition of the poems of Homer formed its subject. For wellnigh twenty years the author had collected evidence, weighed arguments, and patiently tested his results by constant revision. His own bias was strongly engaged on the side of the unity of the great Grecian epic. But the results of his researches continued to point in the opposite direction, and at last his earnest devotion to truth compelled him to adopt a theory the soundness of whose construction seemed to be no longer questionable. He was thus worthy to become the "founder of the science of philology in its present significance."[2]

The influence of Wolf's discovery was not confined to the study of classic literature only. It quickly radiated through every department of history. "In every singing age," he said, "a single sæculum is almost like a single man. It is all one mind, one soul."[3] This conception involved a new social law, and radically altered the current opinions concerning the relation of individual effort to the larger forces that affect the development of nations. The creative energy of remarkable minds was not, indeed, lessened in importance, but spontaneity, in this connection, acquired a new meaning; and for the *Deus ex machina* of the olden time was substituted the cumulative force of centuries of progressive advancement, culminating, it is true, at last in the triumphant synthesis of genius. The commotion which the Wolfian theory has stirred up in the literary world is largely due to the wide range of ideas which it affected. Yet it was itself but a part of that general movement which, toward the close of the last century, became conspicuous in its effects on every field of human inquiry. Everywhere the shackles of authority were thrown off, and, in place of blindly accepting the testimony of the past, men turned to investigate for themselves. A new principle of research was everywhere acknowledged, a new method was created, and science, natural

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[1] "In the estimation of the people for whom these books were written, the capital, essential point surely was, not the historic narrative, but rather legislation and religious edification."—(Nöldeke, "Histoire Littéraire de l'Ancien Testament," p. 19.)

[2] Bonitz, "Ueber den Ursprung der Homerischen Gedichte," p. 11.

[3] In a letter given in Körte's "Leben und Studien F. A. Wolf's," i., p. 307.

and historical, entered upon that astonishing career of discovery whose rich promise for the future we have but begun to anticipate.[1]

To the impetus given by Wolf, and to the new-born spirit of science which he carried into the sphere of philology, we owe among other valuable results the beginnings of a more critical inquiry into the records of ancient Hebrew religion. Indeed, the author of the "Prolegomena" himself clearly foresaw the influence which his book was destined to exert on Hebrew studies. In a letter, from which we have already quoted above, he says: "The demonstration that the Pentateuch is made up of unequal portions, that these are the products of different centuries, and that they were put together shortly after the time of Solomon, may, ere long, be confidently expected. I should myself be willing to undertake such an argument without fear, for nowhere do we find any ancient witness to guarantee the authorship of the Pentateuch to Moses himself."[2]

The prediction embodied in these words soon came true. A host of competent scholars took up the study of the Hebrew Bible, and, profiting by Wolf's example and suggestions, applied to its elucidation the same careful methods, the same scrupulous honesty of interpretation, that had proved so successful in the realm of classical philology. Theologians by profession, they set aside their predilections, and placed the ascertainment of the truth above all other interests. They believed in the indestructible vitality of religion, and were willing to admit the full light of criticism upon the scriptural page, confident that any loss would be temporary only, the gain permanent. In the course of their researches they arrived, among others, at the following important conclusions:

That the editor of the Pentateuch had admitted into his volume several accounts touching the main facts of early Hebrew history; that these accounts are often mutually at variance; that minute analysis and careful comparison alone can lead to an approximately true estimate of their comparative value; and, lastly, that the transmission of historical information had in no wise been the object of the Hebrew writers. The history of their people served, it is true, to illustrate certain of their doctrines concerning the divine government of the world, and especially the peculiar relations of the Deity to the chosen race; but it was employed much in the sense of a moral tale, being designed, not to convey facts, but to enforce lessons. Had the accept-

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[1] Scientific pursuits are distinguished from others, not by the material, but by the method of knowledge. The mere collection of data, however multiplied in detail, however abstruse the subjects to which they may refer, does not of itself deserve the name of science. The term properly applies only when phenomena are placed in causal relation, and the laws which govern their development are traced. Measured by this standard, every attempt to explain the growth of human thought and institutions, and to elucidate the laws which have acted in the process of their evolution, has a just claim to be classed under the head of scientific inquiry.

[2] Letter in Körte's "Leben und Studien F. A. Wolf's," i., p. 309.

ance of any particular scheme of Hebrew history been deemed essential to the integrity of religious belief, the Bible, they argued, would certainly not have included discrepant accounts of that history in its pages. In the light of this new insight, it seemed advisable to draw a distinction between the biblical narrative proper and the doctrines which it was designed to illustrate. The latter belong to the province of faith, and their treatment may be left to the expounders of faith. The former is a department of general history, and in dealing with it we are at liberty to apply the same canons of criticism that obtain in every other department, without fearing to trespass upon sacred ground. It is our purpose in the following pages to present some of the more interesting results that have been reached in the study of the Pentateuch, so far as they illustrate the evolution of religious ideas among the Hebrews. We shall begin by summarizing a few instances of discrepant testimony to introduce our subject, and, in particular, to show how little the ordinary purposes of history have been considered in the composition of the biblical writings; how little the bare transmission of facts was an object with the sacred authors.[1]

Scripture opens with two divergent accounts of the creation. In Genesis i., the work of creation proceeds in two grand movements, including the formation of inanimte and animate Nature respectively.[2] On the first day a diffused light is spread out over chaos. Then are made the firmament, the dry earth, the green herbs, and fruit-bearing trees; on the fourth day the great luminaries are called into being; on the fifth, the fishes and birds of the air; on the sixth, the beasts of the field; and, lastly, crowning all, man, his Maker's masterpiece. The human species enters at once upon its existence *as a pair*. "Male and female did he create them." In the second chapter the same methodical arrangement, the same deliberate progress from the lower to the higher forms of being, is not observed. Man, his interests and responsibilities, stand in the foreground of the picture. The trees of the field are not made until after Adam; and, subsequently to them, the cattle and beasts. Moreover, man is a solitary being. A comparison between his lonely condition and the dual existence of the remainder of the animal world leads the Deity to determine upon the creation of woman. A profound slumber then falls upon Adam, a rib is taken from his side, and from it Eve is fashioned.[3] We may notice that the name Jehovah, as appertaining to the Deity, is employed in the second chapter, while it is scrupulously avoided in the first. The

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[1] Many of the following examples are familiarly known. A few, however, are drawn from recent investigations. Compare, especially, Kuenen, "The Religion of Israel."

[2] Tuch's "Genesis," p. 3, second edition, Halle, 1871.

[3] For an account of the close analogy between the biblical narration and the Persian story of Meshja and Meshjane, their temptation and fall, *vide* ibid., p. 40. It is of special importance to note that reference to the account of Genesis ii. is made only in the later literature of the Hebrews, ibid., p. 42.

recognition of this distinction has led to further discoveries of far-reaching importance, but too complicated in their nature to be here detailed. The conflicting statements of the two accounts, which we have just indicated, have induced scholars to regard them as the work of different writers. In Genesis iv. we learn that in the days of Enosh, Adam's grandson, men began to call on the name of Jehovah; in Exodus vi., on the contrary, that the name Jehovah was first revealed to Moses, being unknown even to the patriarchs.

Gen. xvi., Hagar is driven from her home by the jealousy of her mistress; escapes into the desert; beholds a vision of God at a well in a wilderness. Gen. xxi., the flight of Hagar is related a second time. The general scheme of the narrative is the same as above; but there are important divergencies of detail. As narrated in chapter xvi., the escape took place immediately before the birth of Ishmael. Fifteen years elapsed,[1] and Ishmael, now approaching the years of maturity, is once more driven forth from the house of Abraham. But, to our surprise, in chapter xxi. the lad is described as a mere infant; he is carried on his mother's shoulders, and laid away, like a helpless babe, under some bushes by the wayside. It appears that we have before us two accounts touching the same event, agreeing in the main incidents of the escape, but showing a disagreement of fifteen years as to the date of its occurrence. The narratives are distinguished as above by the employment of different names of the Deity: Jehovah in the one instance, Elohim in the other.

Gen. xxxii., Jacob at the fords of Jabbok, after wrestling during the night with a divine being, receives the name of Israel. Gen. xxxv., without reference to the previous account, the name Israel is conferred upon Jacob at a different place and under different circumstances.

Gen. xlix., the dispersion of the Levites among the tribes is characterized as a punishment and a curse. They are to be forever homeless and fugitive. Deuteronomy xxxiii. and elsewhere, it is described as a blessing. The Levites have been scattered as good seed over the land. They are the apostles, commissioned to propagate Jehovah's law.

Passing on to the second book of the Pentateuch, we pause before the account of the Revelation on Mount Sinai, beyond a doubt the most important event of Israel's ancient history. Exodus xxiv. 2, Moses alone is to approach the divine presence. Exod. xix. 24, Aaron is to accompany him. Exod. xxiv. 13, Aaron is to remain below and Joshua is to go in his stead. Again, Exod. xxxiii. 20, instant death will overtake him who beholds God. Exod. xxiv. 9–11, Moses, Aaron, two of his sons, and seventy elders of Israel "ascended, and they saw the God of Israel. . . . Also, they saw God, and did eat

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[1] Gen. xvii. 25. In quoting from the Old Testament, we follow the order of the Hebrew text.

and drink." Once more, Exod. xxiv. 4–7, Moses himself writes down the words of revelation in a book of covenant. Exod. xxiv. 12, not Moses but God writes them; and, elsewhere, "Two tables of stone inscribed by the finger of God."

Exod. xx. enjoins the observance of the sabbath-day as a memorial of the repose of the Maker of heaven and earth on the sabbath of creation. Deut. v., the fourth commandment is enjoined because of the redemption of Israel from Egyptian bondage. Exod. xxxiv., a new version of the decalogue, differing in most respects from the one commonly received, is promulgated.[1] The first commandment is to worship no strange god; the second, to make no graven images; the third, to observe the feast of unleavened bread; the fourth, to deliver the first-born unto Jehovah; the fifth, to observe the sabbath, etc.

In Exod. xx. we read that the guilt of the fathers will be avenged upon the children down even to the third and fourth generation; in Deut. xxiv., the children shall not die for their fathers. Every one for his own sin shall die.

In Deut. xxv. the marrying of a deceased brother's wife is under certain conditions enjoined as a duty. In Levit. xviii. it is unconditionally prohibited as a crime.

Exod. xxxiii., Moses removes the tabernacle beyond the camp. Num. ii., the tabernacle rests in the very heart of the camp, with all the tribes of Israel grouped round about it, according to their standards and divisions.

Num. xvi., the sons of Korah, the leader of the great Levitical sedition, perish with their father. Num. xxvi., the sons of Korah do not perish.[2]

Of the forty years which the Israelites are said to have dwelt in the desert, not more than two are covered by the events of the narrative. The remainder are wrapped in dense obscurity. There is, however, a significant fact which deserves mention in this connection. The death of Aaron marks, as it were, the close of Israel's journey. Now, while in Num. xxxiii. the death of the high-priest is described as occurring in the fortieth year, in Deut. x. it is actually referred to the second year of the Exodus.[3]

A brief digression beyond the borders of the Pentateuch will show

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[1] Compare De Wette's "Einleitung in das alte Testament" (Schrader's edition), p. 286, note 53.

[2] Num. xxvi. 11. Indeed, had the sons of Korah and every human being related to him perished, as Num. xvi. avers, how could we account for the fact that Korah's descendants filled high offices in the Temple at Jerusalem later on? The celebrated singer, Heman, himself was a lineal descendant of Korah. To the descendants of Korah also are ascribed the following Psalms: Ps. xlii., xliv.–xlix., lxxxiv., lxxxv., lxxxvii., lxxxviii.

[3] In connection with this subject it is of interest to compare Goethe's argument on the duration of the desert journey in the "Westöstlicher Divan." Here, as in so many other instances, the intuitive perception of the great poet anticipated the tardy results of subsequent investigation.

that the conflict of testimony which we have thus far noticed, affecting as it does some of the leading events of ancient Hebrew history, does not diminish as we proceed in the narrative. In 1 Samuel vii. it is said that the Philistines ceased to harass the land of Israel all the days of Samuel. Immediately thereupon we read of new Philistine incursions more direful than ever in their consequences.[1] The popular proverb, "Is Saul among the prophets?" is variously explained, 1 Sam. x. and xix. Two discrepant accounts are given of Saul's rejection from the kingdom, 1 Sam. xiii. and xv.; of David's introduction to Saul, 1 Sam. xvi. and xvii. The charming story of David's encounter with the giant Goliath told in 1 Sam. xvii. is contradicted in 2 Sam. xxi. 19, where, not David, but some person otherwise unknown to fame, is reported to have slain the giant Goliath, and also the time, place, and attendant circumstances, are differently related.[2]

It thus appears that the compiler of the Pentateuch has admitted a variety of views, not only on the ancient history of his people, but also on the general subject of religion and morals, into his work; and that the discordant opinions of diverse authors and of diverse stages of human progress are reflected in its pages. It is the monument of a grand religious movement extending over many centuries of gradual development. It is the image of a nation's struggles and growth. As contained in the books of the Pentateuch, the Mosaic religion is a religious mosaic.

In the foregoing sketch we have observed how deep a mist of uncertainty hangs over the earliest period, the golden age of the history of the Hebrews. All is in a state of flux, and what appeared compact and coherent at a distance yields to our touch upon closer contact. To gain *terra firma*, let us turn to the period which immediately succeeded the settlement of the Israelites in Palestine; a period in which the outline of historical events begins to assume a more definite and tangible shape.

It was a dismal and sorrowful age. The bonds of social order were loosened; the current conceptions of the Deity and the rites of his worship were gross and often degrading. Mutual jealousies kindled the firebrand of war among the contending clans. Almost the whole tribe of Benjamin is extirpated. Abimelech slays seventy princes upon one stone. Lust and treachery run riot. A wilder deed has never been chronicled in the annals of mankind than that related in chapter xix. of Judges, nor ever has a terrible deed been more terribly avenged. Now, looking backward, we ask, Is it to be believed that in the fourteenth century B. C. not only the leader of

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[1] Compare 1 Sam. vii. 13, and 1 Sam. xiii. 19.

[2] In 1 Chron. xx. 5 we read, "the brother of Goliath." The purpose of the change is clear, and accords well with the apologetical tendencies of the author of Chronicles. *Vide* De Wette, "Einleitung," etc., p. 370. Geiger, "Urschrift."

Israel, but also their elders, their priests, nay, large numbers even of the very populace, shared in the most exalted, the most spiritual conceptions of God, and nourished the most refined sentiments in regard to human relationships, while immediately thereupon, and centuries thereafter, violence, and bloodshed, and idolatry, do not cease from the records? It has been argued, indeed, that the worship of idols was but a *relapse* from the purity of a preceding age; and that, though the tradition of the Mosaic time may have been lost in the succeeding period among the people at large, it was still preserved in the circle of a select few, the judges, King David, and others. These, it is believed, continued to remain faithful disciples of the great lawgiver. But these very men, the judges—King David himself—all fall immeasurably below the standard which is set up in the Pentateuch. If they were esteemed the true representatives of the national religion in their day, if the very points in which they transgressed the provisions of the Mosaic code are distinguished by the approval of God and man, we are forced to conclude that that standard—by which they stand condemned—did not yet exist; that, in the days of David, the laws of Moses, as we now have them, were as yet unwritten and unknown. Let us illustrate this important point by a few examples taken from the records. Gideon no sooner returns from victory than he makes a golden idol and sets it up for worship. Jephthah slays his daughter as an offering of thanksgiving to Jehovah. In the Pentateuch the adoration of images is branded as the gravest of offenses. David keeps household gods in his own home (1 Sam. xix.). In the Pentateuch, on its opening page, God is proclaimed as a pure spirit, maker of heaven and earth. In the eyes of David (1 Sam. xxvi. 19), the sway of Jehovah does not extend beyond the borders of Palestine.[1] In the Pentateuch the ark of the covenant is described as the treasury of all that is brightest and best in the worship of the one God. None but the consecrated priest dare approach it, and even he only under circumstances calculated to inspire peculiar veneration and awe. In 2 Sam. vi., David abandons the ark to the keeping of a heathen Philistine. In an early stage of culture, when fear and terror in the presence of superior force entered largely into the religious conceptions of the Hebrews, the taking of the census was deemed an act of grave transgression. It appeared a vaunting of one's strength; it seemed to indicate a defiant attitude toward the loftier power of the Deity, which he would certainly visit with condign punishment. At a later period the priesthood found it in their interest to override these scruples, and the taking of the census became an affair of habitual occurrence. In the last chapter of Samuel the more primitive view still predominated. Seventy thousand Israelites are miserably slain to atone for King David's presumption in commanding a census of the people. In the fourth book of Moses, on

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[1] Banishment being described as a transfer of allegiance to strange gods.

the other hand, the numbering of the people not only proceeds without the slightest evil resulting therefrom, but at the express command of God himself.

In the book of Deuteronomy the service of Jehovah is said to consist mainly in the practice of righteousness, in works of kindness toward our fellows, in sincere and holy love toward the Deity, who is represented as the merciful father of all his human children. 2 Sam. xxi., a famine comes upon the land of Israel. The anger of Jehovah is kindled against the people. To appease him, David offers sacrifice—human sacrifice. The seven sons of Saul are slain, and their bodies kept exposed on the hill, "in the sight of Jehovah," and the horrid offering *is accepted*, and the divine wrath is thereby pacified.[1] Truly, in the age of David, the Hebrews were far, far removed from that high state of culture in which the ideal conception of religion that pervades Deuteronomy became possible. And long after, when centuries had gone by and the kingdom of Judah was already approaching its dissolution, the direful practices of David's reign still survived, and the root of idolatry had not been plucked from the heart of the people. Still do we hear of human sacrifice perpetrated in the midst of Jerusalem, and steeds and chariots dedicated to the sun-god, and images of the Phallus, and all the abominations of sensual worship, filled the very Temple of Jehovah.

But in the mean time a new force had entered the current of Hebrew history. The conviction that one God, and he an all-just, almighty being, rules the destinies of Israel, began to take root. In the eighth century B. C. authentic records prove that monotheism, as a form of religious belief, obtained, at least among the more illustrious members of the prophetic order. We have elsewhere attempted to trace the causes which led to the rise of monotheism at this particular epoch, and shall do no more than briefly allude to them here.

When the mountaineers of Southern Palestine, after centuries of protracted struggle, had secured the safe possession of individual homes, the endearments of domestic life were invested with a sanctity in their eyes never before known. The attachment of the Hebrew toward his offspring was intensified; his devotion to the wife of his bosom became purer and more enduring. Now, the prevailing forms of Semitic religion outraged these feelings at every point. The gods of the surrounding nations were gods of pleasure and of pain; and in their worship the stern practices of fanatic asceticism alternated with the wildest orgies of sensual enjoyment. The worship of Baal Moloch demanded the sacrifice of children; that of the lascivious Baaltis in-

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[1] It is important to note that the seven sons of Saul were sacrificed in the beginning of the barley-harvest. This circumstance seems to throw light on the primitive mode of celebrating the Passover. That the rite of human sacrifice was originally connected with this festival is generally acknowledged. *Vide*, e. g., Exod. xiii., 2. By such offerings it was intended, no doubt, to secure the favor of the god during the continuance of the harvest.

sulted the modesty of woman. The nobler spirits among the Hebrews rebelled against both these demands. And, as they were put forth in the name of the dominant religion, the inevitable conclusion followed that that religion itself must be radically wrong. The spirit of opposition thus awakened was aroused into powerful activity when, in the days of Ahab, the queen, supported by an influential priesthood, determined to introduce the forms of Phœnician religion in Israel by measures of force. The royal edicts were resisted, but for a while the rule of the stronger prevailed. The leaders of the opposition were compelled to flee, and, avoiding the habitations of men, to take refuge in wild and solitary places. Thus the rupture was widened into schism, and persecution inflamed the zeal and kindled the energies of that new order of men of whom Elijah is the well-known type.

Through their agency the emotional nature of the Semitic race now found expression in a form of religious worship loftier by far than any that had ever arisen among men. If Baal was the embodiment of Semitic asceticism and Baaltis the type of sensual orgiastic passion, the national God of Israel now became the type of a nobler emotion, the guardian of domestic purity, the source of sanctity, the ideal Father. It is, indeed, the image of a just patriarch that fills the mind and wings the fancy of the eldest prophets, when they describe the nature of Jehovah, their God. Jehovah is the husband of the people. Israel shall be his true and loyal spouse. The children of Israel are his children. Unchastity and irreligion are synonymous terms. And thus, if we err not, the peculiar feature of Hebrew character, their faithful attachment to kith and kin, the strength and purity of their domestic affections, serves to explain the peculiar character, the origin and development of the Hebrew religion. And because the essential elements of the new religion were moral elements it could not tolerate the Nature-worship of the heathens; and the way was prepared for the gradual ascendency of the purely spiritual in religion, which after ages of gradual progress constituted the last, the lasting triumph of prophecy.

After ages of development! For we are not to suppose that, in the centuries succeeding Hosea, the doctrines of the prophetic schools had become in any sense the property of the people at large. "The powers that be" were arrayed against them, and the annals of the kings are replete with evidence of their sufferings. It was in the late reign of Josiah that they at last received not only the countenance of the reigning monarch, but also a decisive influence upon the direction of affairs. In that reign a scroll was found in the temple imbued with the doctrine of the unity of God, and breathing the vigorous spirit of the prophets. In it was emphasized the heart's religion in preference to the empty ceremonial of priestly worship. The allegiance of the people was directed toward the God who had elected them from among the nations of the earth, and dire disaster was predicted in case of disobedience. When brought to the king and read in his presence, he was powerfully affected, and determined, if possible, to stem the tide of impending ruin by such salutary measures of reform as the injunctions of the newly-found Scripture seemed most urgently to call for. The concurrence of many critics has identified this scroll, written and published at or about the time when the youthful Josiah succeeded to the throne of his ancestors, with Deuteronomy, the fifth of the books of Moses. It differs materially from the more recent writings of the Pentateuch. The family of Aaron are not yet exclusively endowed with the priesthood. The priests are all Levites, the Levites all priests. There are, moreover, other vital differences, into which the limits of this article do not permit us to enter.[1] The date of the composition of Deuteronomy is thus referred to the closing decades of the seventh century B. C.[2]

The princes who succeeded Josiah fell back into the old course, and quite undid the work which had begun with such fair promise. Indeed, little permanent good was to be hoped for in so disordered a condition of political affairs, and from the degenerate rulers who then swayed the helm of state. The fortunes of the kingdom of Judah were swiftly declining, and, but a quarter of a century after the pious Josiah had breathed his last, Nebuchadnezzar burned the Temple of Jerusalem, and carried its inhabitants captive to Babylon.

Heretofore, with but a brief, brilliant interlude, idolatry had been the court religion of Judah. Early training, long usage, the example of revered ancestors, had endeared its forms and symbols to the affections of the people. Resistance to the innovating prophets was natural; men being then, as ever, loath to abandon the sacred usages which had come down to them from the distant generations of the past. But, in the long years of the captivity, a profound change came over the spirit of the Hebrew people; "by Babel's streams they sat and wept;" by Babel's streams they recalled the memories of their native land, that land which they had lost. It was then that the voices of Jehovah's messengers, which had so earnestly warned them of the approaching doom, recurred to their startled recollection. They remembered the message; they beheld its fulfillment; the testimony of the prophets had been confirmed by events; the one God to whom they testified had revealed his omnipotence in history; and with willing assent the exiles promised allegiance to his commandments in the future. The love of country, the dread of further chastisement, the dear hope of restoration, combined to win them to the purer worship of their God, and, in the crucible of Babylon, the national religion was purged of the last dregs of heathendom.

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[1] E. g., the rebellion of Korah is unknown to the author of Deuteronomy.

[2] The language of Deuteronomy attests its late origin. Sixty-six phrases of Deuteronomy recur in the writings of Jeremiah. *Vide* Zunz, *Zeitschrift der Deutschen Morgenländischen Gesellschaft*, xxviii., p. 670.

With the permission of Cyrus, the Jews returned to Palestine, and the Temple at Jerusalem was rebuilt. The question now arose in what forms the ceremonial of the new sanctuary should be conducted. The time-honored festivals, the solemn and joyful convocations, the sacrifices and purifications of the ólden time, were all more or less infected with the taint of paganism. Prophecy would have none of them—prophecy, free child of genius, contemned sacrifice, denounced the priesthood, even the temple and its ritual;[1] proclaimed humbleness and loving-kindness as the true service in which Jehovah takes delight. There was formalism on the one hand, idealism on the other. As is usual in such cases, when the time had arrived for turning theory into practice, it was found necessary to effect a compromise. As Christianity in later days adopted the yule-tree into its system, and lit the lamps of the heathen festival of the 25th of December in honor of the nativity of its founder, so the leaders of the Jews, in the fifth century before our era, adopted the feasts and usages of an ancient Nature-worship, breathed into them a new spirit, informed them with a loftier meaning, and made them tokens, symbols of the eternal God. The old foes were thus reconciled; priesthood and prophecy joined hands, and were thenceforth united. As an offspring of this union, we behold a new code of laws and prescriptions, whose marked and inharmonious features at once betray the dual nature of its progenitors. "A rough preliminary draft, as it were," of this code, is preserved in the book of Ezekiel, composed probably about the middle of the fifth century. In its finished and final shape, it forms the bulk of a still later work—of Leviticus, the third of the books of the Pentateuch: of all the discoveries of criticism, none more noteworthy, none we are bound to consider more assured. What lends additional certainty to the result is the circumstance that it was reached independently by two of the most esteemed scholars of our day, the one a Professor of Theology in the University of Leyden,[2] the other a veteran of thought, whose brow is wreathed by the ripe honors of more than fourscore years.[3] Let us briefly advert to the line of argument by which this astonishing conclusion was reached:

The author of the book of Ezekiel was a priest, and one confessedly loyal to the sanctuary of Jerusalem. Now, had the laws of the Levitical code, which minutely describe the ritual of that sanctuary, existed, or been regarded as authoritative in his day, he could not, would not have disregarded, much less contradicted, their provisions. He does this, and, be it remarked, in points of capital importance. In chapter xlv. of Ezekiel are mentioned the great festivals, with the sacrifices appropriate to each; but the feast of Pentecost, commanded in Leviticus, is entirely omitted; also that of the eighth day of tabernacles. The second of the daily burnt-offerings, upon which the legislator of

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[1] Jeremiah vii. 4; Isaiah lxvi. 1; Micah vi. 6.

[2] Prof. A. Kuenen.

[3] The venerable Dr. Zunz, of Berlin.

the fourth book of Moses dwells with such marked emphasis, is not commanded. The order of sacrifices appointed in Ezekiel is at variance with that in the more recent code. Ezekiel nowhere mentions the ark of the covenant. According to him, the new year begins on the tenth of the seventh month, while the festival of the trumpets, ordained in Leviticus for the first of that month (the present new year of the Jews), is nowhere referred to. We are not to suppose, however, that the festivals, the ark, etc., did not yet exist in the time of Ezekiel. They existed, no doubt, but were still too intimately associated with pagan customs and superstitions to receive or merit the countenance of a prophetic writer. In Leviticus the process of assimilation above described had reached its climax. The new meaning had been successfully engrafted upon the rites and symbols of the olden time; and they were thenceforth freely employed. The legislation of the Levitical code exhibits the familiar features which in every instance mark the ascendency or consolidation of the hierarchical order. The lines of gradation and distinction between the members of the order among themselves are precisely drawn and strictly adhered to. The prerogatives of the whole order as against the people are fenced about with stringent laws. The revenues of the order are largely increased. In the older code of Deuteronomy, the annual tithes were set apart for a festival occasion, and given over to the enjoyment of the people. In the new code, the hierarchy claims the tithes for its own use. New taxes are invented. The best portions of the sacrificial animal are reserved for the banquets of the Temple. The first-born of men and cattle belong to the priesthood, and must be ransomed by the payment of a sum of money. In no period prior to the fifth century B. C. was the hierarchy powerful enough to design such laws. At that time, however, when in the absence of a temporal sovereign they, with the high-priest at their head, were the acknowledged rulers of the state, they were both prepared to conceive and able to carry them into effect. The language of Leviticus contributes not a little to betray its late origin.[1] The authorship of Moses attributed to the Levitical code is symbolical. *The name of Moses is utterly unknown to the elder prophets.* In all their manifold writings it does not occur a single time, though they make frequent reference to the past. There can now be little doubt that the composition of the bulk of Leviticus, and of considerable portions of the books of Numbers, Exodus, and even parts of Genesis, belongs to the epoch of the second Temple, and that the date of these writings may be approximately fixed at about one thousand years after the time of Moses. As to the story of Israel's desert wanderings, it rests upon ancient traditions

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[1] To mention only a single instance, ha Shem (meaning the name, i. e., the ineffable name of God) was not employed until a very late period in the history of the Jews, when the fear of taking the name of the Lord in vain induced men to avoid, if possible, mentioning it at all. We find ha Shem in the above sense in Lev. xxiv. 11.

whose character it is not our present business to investigate. It was successively worked up in various schools of priests and prophets, and this accounts for the host of discrepancies it contains, some of which have been noticed in the beginning of this essay. It was finally amplified by the inventive genius of the second-Temple priesthood, who succeeded in heightening the sanctity of their own institutions by tracing them back to a revered, heroic person, who had lived in the dim days of remote antiquity.

In the preceding pages we have indicated the more important phases of that great conflict which ended in the establishment of monotheism, whose traces, though sometimes barely legible, are still preserved in our records. We saw in the first instance that the Mosaic age is shrouded in uncertainty. We pointed out that pure monotheism was unknown in the time of the early kings. We briefly referred to the rise of monotheism. Finally, we endeavored to show how the prophetic idea had been successively expressed in various codes, each corresponding to a certain stage in the great process of evolution. From what we have said, it follows that the prophetic ideal of religion is the root and core of all that is valuable in the Hebrew Bible. The laws, rites, and observances, in which it found a temporary and changeful expression, may lose their vitality; it will always continue to exert its high influence. It was not the work of one man, nor of a single age, but was reached in the long course of generations on generations, evolved amid error and vice, slowly, and against all the odds of time. It has been said that the Bible is opposed to the theory of evolution. The Bible itself is a prominent example of evolution in history. It is not homogeneous in all its parts. There are portions filled with tales of human error and fallibility. These are the incipient stages of an early age—the dark and dread beginnings. There are others thrilling with noblest emotion, freighted with eternal truths, breathing celestial music. These are the triumph and the fruition of a later day. It is thus by discriminating between what is essentially excellent and what is comparatively valueless that we shall best reconcile the discordant claims of reason and of faith. The Bible was never designed to convey scientific information, nor was it intended to serve as a text-book of history. In its ethical teachings lies its true significance. On them it may fairly rest its claims to the immortal reverence of mankind.

There was a time in the olden days of Greece when it was demanded that the poems of Homer should be removed from the schools, lest the minds of the young might be poisoned by the weeds of superstitious belief. Plato, the poet-philosopher, it was who urged this demand. That time is past. The tales of the gods and heroes have long since ceased to entice our credulity. The story of Achilles's wrath and the wanderings of the sage Ulysses are not believed as history, but the beauty and freshness and the golden poetry of the

Homeric epic have a reality all their own, and are a delight and a glory now, as they have ever been before. The Bible also is a classical book. It is the classical book of noble ethical sentiment. In it the mortal fear, the overflowing hope, the quivering longings of the human soul toward the better and the best, have found their first, their freshest, their fittest utterance. In this respect it can never be superseded.

To Greek philosophy we owe the evolution of the logical categories; to Hebrew prophecy, the pure canon of moral principle and action. That this result was the outcome of a long process of suffering and struggle cannot diminish its value in our estimation. When we compare the degrading offices of the Hebrew religion in the days of the judges with the lofty aspirations of the second Isaiah, when we remember the utter abyss of moral abasement from which the nobler spirits of the Hebrews rose to the free summits of prophecy, our confidence in the divine possibilities of the human soul is reinvigorated, our emulation is kindled, and from the great things already accomplished we gather the cheering promise of the greater things that are yet to come. It is in this moral incentive that the practical value of the evolutionary theory chiefly lies.[1]

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# PRESENT STATUS OF SOCIAL SCIENCE—REPLY TO A CRITIC.

By ROBERT S. HAMILTON.

WHEN a periodical of such wide circulation and deservedly high reputation as THE POPULAR SCIENCE MONTHLY disparages an author by its criticism, silence on his part might reasonably be construed into acquiescence in its justness. It is, therefore, hoped that this reply to a criticism on the late work, published by H. L. Hinton & Co., on "The Present Status of Social Science," which appeared in that monthly for May, 1874, will not be denied a place in the same columns that allowed the criticism.

The main accusation preferred against the book—and it is almost the only one—is, that it is "an old book," and of "an antiquated character."

It may not be out of place here to remind our critic that some of the

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[1] Most aptly has this thought been expressed in the lines with which Goethe welcomed the appearance of F. A. Wolf's "Prolegomena:"

> "Erst die Gesundheit des Mannes, der, endlich vom Namen Homeros
> Kühn uns befreiend, uns auch führt in die vollere Bahn.
> Denn wer wagte mit Göttern den Kampf? und wer mit dem Einen?—
> Doch Homeride zu seyn, auch nur als letzter, ist schön."
>
> *The Elegy of Hermann und Dorothea.*

oldest books in the world are among the most valuable, that age does not necessarily detract from the real merit of a book, or of any truth it may advocate, any more than it does from the quality of wine, or of ancient, long-tried, long-approved friendship, *that an old truth is even better than a new error*, and that one of the highest and most important functions of the philosopher, in every age, is to reconcile the new with the old, to harmonize the latest revelations of science with the venerable traditions and immutable ideas of the race; in short, to keep mankind constant, and bring them back to the *old landmarks*, the primary and fundamental truths, from which they have a constant tendency to wander off and go astray. Perhaps it might not be amiss, furthermore, to remind him that the present age, more than any other, and especially this department of science, require to be admonished with the warning proverb of Solomon, "Remove not the ancient landmarks which thy fathers have set."

But with what propriety can a book be called old, or antiquated in character, that deals almost exclusively, and that, too, with almost unqualified approbation and accord, with the views of such recent and highly-advanced thinkers as Guizot and Hallam, Sismondi and Mill, Cousin, Buckle, Comte, and Herbert Spencer?

If the book in question is old, all that Herbert Spencer has written on sociology is likewise old. If there is nothing new in this book, there is nothing new in any of the reasonings, on society, of that Magnus Apollo, we might almost say, that *alter ego*, of THE POPULAR SCIENCE MONTHLY. We challenge our critic to produce a single idea of Herbert Spencer's, having any important bearing on the philosophy of society, and any claim to be considered at all new, either in his "Social Statics," or any other of his works, that is not contained in the "Present Status of Social Science," either in direct expression, or in fair, direct, and inevitable logical sequence, from what is directly expressed. Will our critic accept the challenge, with the privilege of only a brief reply accorded to a misrepresented and much-wronged author? We hardly think so.

The truth rather seems to be, that the work in question contains rather too much about Mr. Spencer and his philosophy of society. It contains, *substantially*, not only all that is true or essentially valuable in the suggestions of that great and eminently valuable thinker, up to the present time, but something that is not so valuable or true. It contains, in short, a rather too caustic, possibly too just, and unanswerable criticism on his extreme and exaggerated applications of the *laissez-faire* doctrine, and upon his fantastical reasonings about "the evanescence of evil." It takes too just exceptions to his condemnation of any and all provision, by the state, for the relief of the poor, or even for their education.

But the plea of our critic, which is plausible only on its face, is, that it was unfair, unjust, thus to attack Mr. Spencer, when his views had not as yet been fully presented to the world. On this point, which is the main point, he says: "An example of the antiquated and unreliable character of the work is afforded by the author's treatment of the most eminent thinker of the times on problems of social science. Mr. Herbert Spencer is judged as a sociologist by his views developed in 'Social Statics;' how justly will appear from the fact that 'Social Statics' was Mr. Spencer's first work, published twenty-four years ago. And not only this, but he was so dissatisfied with it that he would not consent to its republication in this country without incorporating a preface, which indicated that his views had undergone important modifications."

Now, what does our critic mean by the equivocal expression, "Mr. Spencer is judged," etc., "by his views expressed in 'Social Statics?'" Does he mean that he has been judged in part, or altogether and solely, by his "Social Statics?" If the former only, what is the ground of complaint? What more fair, or just, than that an author should be judged, in part, by a part of his performance, by one of his most formal and elaborate works? If he means the latter, then he is greatly mistaken, and grossly misrepresents the author. Mr. Spencer is judged in the work in question, not only by his "Social Statics," but by his brilliant article on "The Social Organism," to be found in his "Illustrations of Universal Progress," by his truly great work on "First Principles," in which are contained some of his most valuable thoughts on sociology,[1] and to some and not unimportant extent, also, by his "Principles of Biology," and other writings.

And now to the main point of the criticism, its very citadel, which, briefly rendered, is, that Mr. Spencer has been judged, at least to a very large and important extent, by a work which he has virtually retracted or disclaimed, in some of its essential doctrines. On this point, as will be seen, the critic expresses himself with a very cautious reserve, gently insinuating, merely, what he could hardly venture directly to assert. In reference to the preface, which Mr. Spencer insisted on incorporating with the republication of the "Social Statics," in this country, he says it "indicated that his views had undergone important modifications."

Now, we must beg leave, most respectfully but most emphatically, to dissent from the critic's interpretation of Mr. Spencer's preface in question, and to say that it indicated, very clearly, that his views had undergone only *some slight and unimportant modifications.* The precise words of Mr. Spencer's preface, on this point, are "some accompanying modifications." But the whole context conclusively demonstrates that "those modifications" were not important, not material, in respect to the essential or substantial import of his ideas.

He begins his preface by saying he would not have the American public to take this work as "a literal expression" of his present

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[1] *See* "Present Status," etc., pp. 126–128, or chapter vi., § 12.

views. He proceeds to say that now, after the lapse of fourteen years, were he writing out his thoughts on the subject, he would express himself somewhat differently on several specified points. Then by way of excusing himself from rewriting his views, and of showing the little importance of his doing so, he concludes his preface with these conclusive words, expressing himself in the third person: "When, however, he comes to the closing volumes of this system, should he ever get so far, he proposes to set forth in them the developed conclusions of which 'Social Statics' must be considered a rough sketch." What more conclusive proof could we need that "Social Statics" was still, then and there, a *substantial* embodiment of his views?

The critic says that the author of the work in question appears to have "an obscure conception of social science," etc. It is to be remembered, however, that social science is a very large science, susceptible of very diverse renditions, or modes of consideration, and that, when viewed, as it is by Mr. Spencer and his especial admirers, from the lofty standpoint of universal science, it would be likely to present somewhat different points of prominence for scientific consideration from those it would present from the far less ambitious standpoint from which it is viewed by the author in question—the standpoint of the practical statesman and jurist.

By way of illustrating the fairness and justness of his criticism, the critic quotes an isolated passage from the work under his consideration, which, unexplained, and rent from its context, would appear only as Greek, Hebrew, or Sanscrit, to the general reader; a passage in which, after the example of Mr. Spencer himself, and other modern scientists, the author had casually drawn on astronomical science for illustration, and instituted a similitude between the forces of cosmical and social life. But was that a really fair selection? What would our critic think if any one should undertake to judge Mr. Spencer, either as a sociologist or a general scientist, solely by his fundamental postulate that all evolution is from the *homogeneous* to the *heterogeneous?*

The critic would have conveyed to his readers a far more just idea of the scope and real character of the work under his review—a mere preliminary work as it is—if he had seen fit to quote the *seven propositions* laid down in the author's sixth chapter, embodying, as they claim to do, the essential import of all the most recent and most advanced thought in social philosophy; nay, embodying, in outline, the very quintessence of Mr. Spencer's peculiar views, with the addition of only a few highly-important ideas, which he seems to have either overlooked or undervalued.

And here it may be proper to remark that there is no essential antagonism between Mr. Spencer and the author who has incurred the displeasure of THE POPULAR SCIENCE MONTHLY. On fundamental principles, and in the general drift of their reasonings, likewise, they are in almost perfect accord—co-laborers in the same great field—endeavoring to compass it only by different methods.

While Mr. Spencer is tugging at the vast problems of social science from the standpoint of the universal scientist, the author in question is viewing them more directly from the standpoint of the specialist in *sociology*—and more particularly in the department of *statesmanship*—seeking and deriving valuable instruction from the vast generalizations of his more able and far more learned co-laborer.

Can it be supposed, however, that the two laborers will not differ, somewhat, in some of their practical applications of the very same general principles which they hold in common? Or need it be wondered at that, while Mr. Spencer would abolish the state school and state provision for the poor, the author in question would rather remodel and enlarge the scope of both, while admitting and appreciating the great abuses and mischiefs that may result from either?

Does not the very loftiness of Mr. Spencer's standpoint, the grandeur of his views, and the vast and far-reaching comprehensiveness of his observations, make it impossible, despite his great and indisputable sagacity, to avoid some mistakes in respect to the great practical problems of social life, and to escape altogether the error, so common with our modern reformers, of seeking to abolish institutions that need only amendment and reform?

In conclusion, let the hope be expressed that "the antiquated character" of this reply will find excuse in the fact that, although the privilege of making it was solicited early in June, 1874, it was not accorded until late in October following, when the author, in despair of obtaining justice, or a fair hearing, at least in this country, had abandoned all idea of replying. Weeks and even months then elapsed before the purpose of doing so revived in his mind, under the conviction that such a course was due, not only to himself, but to the momentous theme, which he has made the theme of his life, and on which he feels a strong assurance that he has some suggestions to offer, some great universal truths, *great fundamental laws of social life*, to announce, that are calculated to exert an important influence on the cause of knowledge and human advancement.

CINCINNATI, *February* 22, 1875.

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## SKETCH OF PROF. WILLIAM B. ROGERS.

THE President of the American Association for the Advancement of Science, who presides at its meeting this year in Buffalo, belongs to a family which has attained eminent distinction in the field of American science. He was born in Philadelphia, in December, 1805, and is the second of four sons—James Blythe, WILLIAM BAR-

TON, Henry Darwin, and Robert Empeie Rogers, all of whom have won celebrity as scientific teachers and investigators, and of whom William and Robert alone survive.

Their father, Patrick Kerr Rogers, was a man of varied attainments, and an enthusiastic student and teacher of natural science, who, besides lecturing to medical classes, was among the first in this country to establish systematic courses of instruction in chemistry and experimental physics for the general public. His sons were educated chiefly at home under his immediate care, the elder continuing their studies at William and Mary College, their father having been appointed Professor of Natural Philosophy and Chemistry in that institution.

When twenty-one years of age, William gave his first lectures on science in the Maryland Institute, Baltimore, and the following year was appointed to succeed his father in William and Mary College, where he remained until 1835. He was then appointed to the chair of Natural Philosophy in the University of Virginia, and there extended his instructions by adding the subjects mineralogy and geology to his course. The same year he organized the geological survey of the State, having, while a professor at William and Mary, begun his geological labors with an examination of the Tertiary region, of which he published, in conjunction with his brother, Henry D. Rogers, two memoirs in the "Transactions of the American Philosophical Society." At this time, besides other chemical researches, he made an analysis of the waters of the Virginia mineral springs, the results of which have appeared in various publications.

He remained at the head of the geological survey until it was discontinued in 1842, having published a series of annual reports and collected further materials, for the completion and publication of which, however, no provision was made by the State. While at the university he published for the use of his students a short treatise on the "Strength of Materials" (Charlottesville, 1838), and a volume on "The Elements of Mechanical Philosophy" (Boston, 1852). During this period of his life, besides the cares of his professorship and of the survey, he occupied himself with original researches in various departments of science, partly geological, in connection with his field-work, and, after the survey ended, chiefly in chemistry and physics.

In 1840 the "Association of American Geologists and Naturalists" was organized. In this society, embracing Hitchcock, Hale, Vanuxem, the four brothers Rogers, Conrad, Emmons, and others, engaged in active scientific research, Prof. Rogers took a leading part, as will be seen by referring to the volume of its "Transactions" (1840–'42), to which he contributed among other articles the following memoirs: "On the Age of the Coal-Rocks of Eastern Virginia;" "On the Connection of Thermal Springs with Anticlinal Axes and Faults;" "Observations of Subterranean Temperature in the Coal-

Mines of Eastern Virginia;" and "On the Physical Structure of the Appalachian Chain," etc. In the first of these papers Prof. Rogers showed that the formation in question, instead of being of an age anterior to the Carboniferous, as had been maintained by Maclure and R. C. Taylor, was of Mesozoic time. In the second paper he described the position of more than fifty thermal springs in the Appalachian belt, occurring in an area of about 15,000 square miles, deducing the law that these thermal springs issue from anticlinal axes and faults, or from points very near such lines, and, in connection with their chemistry, proving the important fact of the great preponderance of nitrogen in the free and combined gases of these springs. The observations on subterranean temperature recorded in the third paper were the first published confirmation, as regards the United States, of the law of augmenting temperature beneath the surface of the earth, although similar observations had been made by Humboldt in Mexico. The memoir on the physical structure of the Appalachian chain, etc., was the joint work of Profs. W. B. and H. D. Rogers, founded on their explorations of this belt in Pennsylvania and Virginia, and its prolongation toward the southwest and northeast. The novelty and importance of its generalizations were at once recognized in Europe as well as at home, and gave the authors, "the Gebrüder Rogers," a prominent place among contemporary geologists; and, so far as the development of the physical structure of the Appalachians is concerned, this memoir is still regarded as of classical value.

Prof. Rogers was chairman of the Association in 1845, and again two years later, when it was expanded into the "American Association for the Advancement of Science," at the first meeting of which he presided until it was fully organized.

In connection with his brother, Robert E. Rogers, now become his colleague as Professor of Chemistry and Materia Medica in the university, he published a number of important chemical contributions, relating chiefly to new or improved methods in chemical analysis and research, in *Silliman's Journal*, between 1840 and 1850. Among these were papers "On a New Process for obtaining Pure Chlorine;" "A New Process for obtaining Formic Acid, Aldehyde, etc.;" "On the Oxidation of the Diamond in the Liquid Way;" "On New Instruments and Processes for the Analysis of the Carbonates;" "On the Absorption of Carbonic Acid by Liquids," an extended investigation; and "On the Decomposition of Rocks by Carbonated and Meteoric Waters," a paper of much interest in its geological bearings.

In the volume of the "Transactions of the British Association" for 1849, Prof. Rogers called attention to the existence of true coal-measures below the horizon of the Carboniferous limestone in the Appalachian belt as discovered by him in the Virginia survey, and referred to in his annual reports.

He married, in 1849, a daughter of Hon. James Savage, of Boston, President of the Massachusetts Historical Society, and author of the "Genealogical Dictionary," and in 1873 removed to that city, where he has since resided. Here, although he early identified himself with the educational and public interests of the community, he did not relax his devotion to scientific labors, which were now, however, more largely directed to the department of experimental physics. Among his contributions to physics at this period may be mentioned a series of papers "On Binocular Vision, giving an Elaborate Analysis of the Phenomena, with some Important Additions to the Researches on this Subject of Wheatstone and Brewster;" "Experiments on Sonorous Flames," in which he described an apparatus for making visible the vibrations by rotating the flame; and "On the Formation of Rings of Air and Liquids"—all of which may be found in *Silliman's Journal* (1855–'60).

He also published, in the *New Edinburgh Philosophical Journal*, the results of continued observations on atmospheric ozone, and on the auroras of August and September, 1859 and 1860. As a member of the American Academy of Arts and Sciences, and of the Boston Society of Natural History, of the former of which he was for many years the corresponding secretary, Prof. Rogers took an active part in the discussions of the various scientific questions then rising into importance, and made contributions from time to time to their published proceedings. Among the communications to the American Academy we may note papers "On the Protozoic Age of Certain Rocks in Eastern Massachusetts;" "On the Actinism of the Electric Discharge in Vacuum Tubes," of which he exhibited numerous photographs, in connection with his paper on the improvements, by Mr. E. S. Ritchie, of the Ruhmkorff apparatus; and "Experiments disproving, by the Binocular Combination of Visual Spectra, Brewster's Theory of Successive Combination of Corresponding Points."

In the "Transactions of the Boston Society of Natural History" appeared, among other articles by Prof. Rogers, communications "On the Growth of Stalactites;" "Geological Relations of the New Red Sandstone of the Middle States to the Coal-Rocks of Eastern Virginia and North Carolina;" "On the Origin and Accumulation of the Protocarbonate of Iron in Coal-Measures;" "On the Natural Coke and Associated Igneous Rocks of Eastern Virginia;" and "On Pebbles in the Newport Conglomerate."

At the annual meetings of the American Association for the Advancement of Science, Prof. Rogers has been a frequent contributor, as well in the discussions of scientific questions as in the communication of original papers, which, however, in most cases, appear only by title in their "Transactions," or are to be found in other publications before mentioned.

In 1853 he removed to Boston, where he has since resided. At the request of his friend Governor Andrew, in 1861, he accepted the office of Inspector of Gas and Gas-Meters for the State of Massachusetts, and organized a system of inspection in which he aimed to apply scientific principles more fully than had hitherto been attempted in the United States. Some account of his methods was given at a meeting of the British Association. During this time Prof. Rogers was often called upon for public lectures on scientific subjects in Massachusetts and elsewhere, and gave several courses before the Lowell Institute in Boston.

Prof. Rogers had long felt the need, in our educational system, of giving to the physical sciences a higher place and more practical methods of teaching than had hitherto been allowed them, and he was therefore eager to avail himself of the opportunity for carrying out these views. In behalf of a committee of gentlemen who had become interested in the subject, he drew up a scheme entitled "Object and Plan of an Institute of Technology," embracing a society of arts, a museum of arts, and a school of industrial science; and he subsequently addressed a memorial to the Legislature of Massachusetts, urging the establishment of such an institution. After some delay a charter for the "Institute of Technology" was granted, and Prof. Rogers was placed at its head. A whole square of land on Back Bay was granted for building-purposes—one third to the Boston Society of Natural History, the other two thirds to the Institute of Technology. But the popularity and increasing prosperity of the Institute make it already cramped in its present stately hall, and it will soon be necessary to have another edifice. The detailed plan for the departments of the school, prepared by Prof. Rogers in 1864, has been carried out, with but slight modifications. A marked feature of this plan, which has since been adopted in many other institutions, was the introduction of laboratory teaching, not only in the department of chemistry, but in that of physics, mechanics, and mining, a feature which has no doubt contributed largely to the reputation which the school has acquired for thoroughness of scientific training.

Besides being president of the Institute, Prof. Rogers filled the chair of Physics and Geology for several years after the establishment of the school. It may be added that he was active in founding the American Social Science Association, and was its first president.

But this inventory of the life-work of Prof. Rogers, extensive and interesting as it is, leaves out a powerful element of the influence he has exerted as a teacher over great numbers of young men who have been brought within the spell of his personality. Prof. Rogers is an orator of the first class, and we have long regarded him as the most impressive and delightful speaker that has appeared before the American Association. And it must be remembered that science puts oratory to its highest test; it is a field in which reason is supreme, and where the speaker is not at liberty to throw logic to the winds, and make his fiery appeal to the feelings and passions of listeners. The scientific orator must address intelligent men, habituated to think for themselves, on the alert against tricks that carry the imagination, while the speaker himself is kept under the close restraints of fact. To be able to captivate and enchain an audience in the pure work of exposition, to fascinate in teaching, is a triumph of oratorical art. Prof. Rogers has been marked by the possession of this rare gift, and before his classes in college, whether treating of rocks, physical forces, or rigid principles of mathematics, he was always able to kindle the enthusiasm of the students, and make the most vivid and lasting impressions upon their minds. We were not surprised, therefore, to note, in a Virginia newspaper of last year, an exciting description of the way Prof. Rogers was received by his old students at the semi-centennial of the University of Virginia, where he "was the central object, on whom were fixed the eyes and hearts of the great concourse there assembled from all parts of the country. It was difficult to get near enough to speak to him, surrounded as he was by such numbers of those who in years long past had attended his lectures." He made an address, the reception of which is described by the writer with a pardonable warmth: "At the dinner of the alumni, Prof. Rogers addressed them in a speech of half an hour. It was a wonderful specimen of eloquence. The old students beheld before them the same William B. Rogers who, thirty-five years before, had held them spellbound in his class of natural philosophy; and as the great orator warmed up, these men forgot their age; they were again young, and showed their enthusiasm as wildly as when in days of yore, enraptured by his eloquence, they made the lecture-room of the university ring with their applause. Such was the effect produced by the off-hand words of this distinguished man of science and unrivaled orator; and those who have heard him in his moments of inspiration will not wonder at the account we have given."

Some time ago failing health compelled Prof. Rogers to retire from the active direction of the Institute. He still, however, has a share in its government, and his returning strength for the last two or three years has enabled him gradually to resume his favorite pursuits.

# CORRESPONDENCE.

## A STONE BATTLE-AXE.

*To the Editor of the Popular Science Monthly:*

I HEREIN give you the outlines of a large-sized battle-axe, found in a thick bed of drift on the elevated surface of Rose or Cemetery Hill, Cumberland, Maryland. This locality is situated on the first plateau at the base of Will's Mountain, on the south side of Will's Creek, and east side of the mountain, and within the limits of the city of Cumberland.

The unassorted drift that spreads over this plateau for miles, and which lies about two hundred and fifty feet above the bed of Will's Creek, varies in thickness from two to ten, and in some places twenty feet, and the point at which this implement of the Paleolithic age was found is about five or six feet beneath the original surface—the soil, gravel, sand, and water-worn bowlders having been carried over the declivity into Will's Creek by rains or other means.

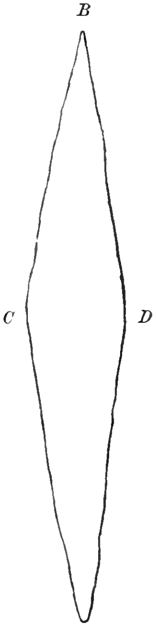

Fig. 1.—*A*, pole; *B*, blade. Length from *A* to *B*, 10¾ inches; thickness from *C* to *D*, 2⅝ inches.

This remarkably large relic of by-gone ages has a very sharp edge, compared with hundreds of the small Indian axes and hatchets, so called, found in many parts of this country. It weighs seven and a half pounds, measures eight and a half inches around the sharp edge of the blade; it is ten and a half inches long, seven and three-quarters inches across the widest part of the blade; is two and five-eighths inches through from side to side, and tapers gradually toward the pole to a sharp point, in a

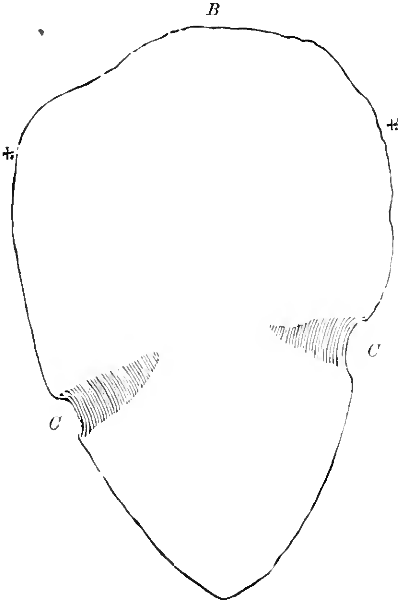

Fig. 2.—*A*, pole; *B*, blade, edge very sharp from mark to mark +, then thickens abruptly; *C C*, thong-marks.

The lithological character of this relic of the Stone age is that of a dark-blue cherty, siliceous and coralline limestone of the Paleozoic age, and, possibly, of an upper silurian stratum, as it very much resembles some of those fossiliferous strata, and, in fact, presents on one side what very much resembles a large (but not very distinct) polyparium of the fossil coral lichenalia concentrica of Prof. Hall's "Paleontology of New York," vol. ii., Plate 37, A.

similar manner to the stone axes of the ancient Celtic tribes, so frequently found in some portions of England, Ireland, and Scotland.

On the plateau above named, bowlders of many hundred weight are thickly scattered, which could have been deposited in their present locality by floating ice only, and it is more than likely that this relic of the Primeval or Stone age was brought to this locality and deposited by the same agencies that brought the bowlders and other detritus, perhaps, from a very distant region.

The thong-marks for securing the handle are well preserved, but were deeper when first taken from the ground, as there was a full sixteenth of an inch of semi-decomposed material rubbed off in cleaning it up. The stone from which it has been made appears to have been a portion of one of those hard, cherty strata of coralline limestone, belonging to the silurian formation, some of which are harder than flint, and almost as tough as iron. The implement, as it is now, is dark blue on one side, but lighter on the other. This lighter side appears to have yielded more readily to the action of the elements, decomposition having apparently removed at least a quarter of an inch more on this side than on the other, thus materially reducing the weight of the specimen. This battle-axe was found on January 4, 1876. William Andrews.

Cumberland, Maryland.

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*To the Editor of the Popular Science Monthly:*

Sir: In your notice of Mr. John Fiske's criticism of Dr. Draper's "Conflict" you have shown, plainly enough, that Dr. Draper's alleged superficiality consisted in using the word religion in the common sense.

That Dr. Draper's conceptions are so "crude" as to blind him to the higher and more spiritual conceptions which Mr. Fiske defines so admirably, or that he would consider religion, so defined, in antagonism with science, is an assertion which finds no warrant in his book. It would be easy, if it were worth while, to point to passages that explicitly negative such imputations. But to have adopted Mr. Fiske's rather transcendental refinement, and to have constantly used the qualified terms which it would require, would have been to sacrifice directness and brevity to a nicety of expression that none but the hypercritical would demand.

Your quotation shows that Mr. Spencer's "First Principles" must fall within the list of books which, "vitiated by this crude conception" (of antagonism), "cannot have much philosophical value;" and I beg to append another from a work which, it would seem, must come into the same class, although it is by an author evidently held in high esteem by Mr. Fiske:

"*That harmony which we hope eventually to see established between our knowledge and our aspirations* is not to be realized by the timidity which shrinks from logically following out either of the two apparently conflicting lines of thought—as in the question of matter and spirit—but by the fearlessness which pushes each to its inevitable conclusion. *Only when this is recognized will the long and mistaken warfare between Science and Religion be exchanged for an enduring alliance.*"—(Fiske's "Cosmic Philosophy," vol. ii., p. 509.)

E. R. Leland.

Eauclaire, Wisconsin, *July* 20, 1876.

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## GEOMETRICAL CHEMISTRY.

*To the Editor of the Popular Science Monthly:*

Geometrical Chemistry. By Henry Wurtz. First, or Introductory Memoir. Reprinted from the *American Chemist*, for March, 1876. New York: John F. Trow & Son. 1876.

The author prefixes a Greek motto to his memoir, namely, the question, "Wherefore did Plato assert that *the* God worketh ever by geometry?" As the memoir contains no other geometry, this motto apparently is intended to justify the first half of the title.

But the other half has not even that much of a justification. From beginning to end it is impossible to detect a new principle or fact that properly belongs to chemistry in this memoir. The great chemical authorities of the memoir are Kant, Hegel, Stallo, and Sterry Hunt (p. 60). A new force, the *Cratetic Force*, is discovered, "which is *not* reciprocal, but absolute in its action upon the more electro-positive molecule, *without reac-*

*tion* upon the electro-negative one" (p. 69). Hence the equality of action and reaction must now be thrown to the resting-place of *horror vacui* and kindred errors.

Having reached the end of the memoir without encountering a single scientific result, I felt greatly relieved by the author's modest statement (p. 72): "I claim to have discovered and demonstrated the same grand geometrical laws which Kepler traced as ruling the planetary system, as prevailing also in the microcosms which we call molecules." And the author complacently continues: "I must add that, though many advanced chemists have long expected some great revelation from this source, yet *now that a revelation has come*, there are few even among the boldest and most original thinkers who will not be *startled* at the sweeping, in some respects revolutionary, tendency of these developments, with regard to the current theories of the schools and the school-books."

I confess to have indeed been thoroughly "startled" to see such a paper as this printed *in extenso* in the *American Chemist;* and not much less astonished to find it recently (May 27, 1876) partly reprinted in the *Engineering and Mining Journal*, accompanied by a highly-laudatory editorial, wherein Dr. T. Sterry Hunt is reported to have expressed the opinion that "Prof. Wurtz has surprised Nature in one of her secrets, and has enunciated a law which is probably as important as the law of the force of gravity."

It is simply because these high and unqualified indorsements are likely to give the vagaries of "Geometrical Chemistry" currency in the popular scientific press of the country that I take the trouble to expose the palpable fallacy of the whole fabric.

The inorganic chemical compounds contain oxygen as the most general constituent, while the organic compounds contain as generally carbon. Hence, if we were to mystify some of our chemical colleagues, not very sound in elementary mathematics, we would calculate the densities of all compounds by assuming almost any fixed atomic volume for these two elements, and assigning the residual volume to the other constituents. By a liberal use of arbitrary multiples, these residual volumes could then be very readily expressed as cubes (or almost any other function) of whole numbers with so great an approximation that inversely the calculated density of the compound must be almost identical with *any*[1] of the observed values of the same. Such a process, when presented by a sufficiently funny man in Section Q of the American Association, would be very entertaining; but when such a thing occupies twenty quarto pages in the *American Chemist*, and when voluminous extracts thereof in other scientific journals are printed as embodying great chemical progress, I feel that American science has been disgraced.

Prof. Wurtz in the above mystification proves himself not even sufficiently master of arithmetical puns to keep the variations of the positive elements (the above residual) within bounds. A slightly more dexterous use of the convenient arbitrary multiples would have helped him out, and yielded numerous new "laws." Thus the hydrogen diameter ranges from 16 to 28, that is, in volume it ranges as the cubes of these numbers, from 4,096 to 21,952, in proportion of one to five in closely-allied compounds! In very closely-related compounds of aluminium the diameter of aluminium varies from 16 to 45, its volume therefore from 4,096 to 91,125, or in the proportion of one to twenty-two! (*See* pp. 54–57.)

Space forbids my entering upon a more detailed *exposé* of this crude display of indeterminate analysis. The whole thing is so utterly worthless, so absolutely destitute of every gleam of science, so horridly uncouth even in its verbal exposition, that this short notice is most reluctantly given, simply to protest, in the name of American science, against the filling of our *scientific* journals with material that exposes us to the ridicule of the scientific world.

Gustavus Hinrichs.

Iowa City, Iowa, *July* 21, 1876.

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[1] The influence of impurities, etc., is coolly ascribed to arbitrary variations in atom-diameter and varying multiples in the molecule; this is done even for minerals and metals! I wonder that Mr. Raymond did not see the absurdity of the whole process. See, for example, "Siderite," p. 32, or in fact any substance for which more than one density has been used.

# EDITOR'S TABLE.

## FRENCH EXPERIENCES WITH PAPER-MONEY.

IN his pamphlet entitled "Paper-Money Inflation in France: How it came, What it brought, and How it ended," President White tells a very plain and direct, but a very exciting story of national folly and infatuation. It sounds like romance, and but for the constant citations we should almost suspect that the writer is treating us to a satire on American finance. Yet he only gives us a cool, matter-of-fact delineation of a great national experiment in the substitution of irredeemable paper for coin as a circulating medium. The lesson brought out by this impressive narration is, that there are natural laws which govern the business operations of society just as inexorable as the physical laws that maintain the harmonies of the solar system or the physiological laws that control the life-processes of the human body. But in the realm of social operations this truth is not recognized. In consequence of public ignorance upon this point, and the stupid superstitions of the people regarding the potency of legislation, this great field of human effort is the intrenchment of imposture in a hundred shapes, where designing quacks and credulous dupes, calculating demagogues, purblind reformers, and humbugs of every stripe, have free course and unrestrained revel. This is a sphere in which it is believed that Nature can be cheated, and the consequences of human actions escaped. The laws that connect human well-being with self-restraint, that require present sacrifice for future good, and make comfort and competence dependent upon industry and frugality, are held to be the mere hard conditions of human lot, which, being evaded by many, may be avoided by all through cunning political schemes and proper legislative ingenuity. There are still millions in this country who have a kind of vague faith that irredeemable paper-money such as a government can print and scatter without limit is a means of national prosperity, a fountain of public wealth, an equalizer of fortunes, a blessing to the poorer classes, and a grand defense of society against the evils of poverty and privation. That it is an illusion and a snare, full of danger, and offering transient benefits at the expense of final disaster, it is difficult to make them understand.

Let people in this state of mind acquaint themselves with the experience of the French upon the subject by reading President White's statement. We give its leading points, quoting his own words freely: The year 1789 was one of stagnation and financial embarrassment in France. The nation had a heavy debt and a serious deficit, and there was scarcity of money and a want of confidence. This was a time of trial and a test of statesmanship. There were those who saw that the evil could only be remedied by patience, careful management, and the strict adherence to established financial principles. But others, as Dr. White says, were "looking about for some short road to prosperity, and ere long the idea was set afloat that the great want of the country was more of the circulating medium; and this was speedily followed by calls for an issue of paper-money." There was then a struggle. The dangers of such a course were vividly depicted on the one hand, and on the other it was maintained that it would be the salvation of France. On the 19th of April, 1790, the finance committee of the

French Assembly reported that "the people demand a new circulating medium;" that "the circulation of paper is the best of operations;" that "it is the most free, because it reposes on the will of the people;" that "it will bind the interests of the citizen to the public good."

The Government had appropriated the vast property of the French Church, amounting in value to about four thousand million francs, and this was to be the security of the paper. Accordingly, in April, 1790, the "Government issued four hundred million francs in assignats—paper-money secured by a pledge of productive real estate, and bearing interest to the holder at three per cent." What could be more secure? It was maintained that such a currency would immediately prove itself better than coin.

"The first result of this issue was apparently all that the most sanguine could desire; the Treasury was at once greatly relieved; a portion of the public debt was paid; creditors were encouraged; credit revived; ordinary expenses were met, and the paper-money having thus been passed from the Government into the midst of the people, trade was revived, and all difficulties seemed past."

Possibly, if the Government could have stopped with these temporary advantages, no great harm would have been done. But the difficulty about money is, that there is never thought to be enough of it. The benefit of real money (coin) is to set a stubborn limit to this universal want—it cannot be got without earning it or giving equivalent property for it. The curse of pseudo-money (irredeemable paper) is, that it panders to the universal greed because any amount of it can be manufactured and set afloat at any time. And so, of course, the French, after the first taste, wanted more. The further issue was stoutly resisted by the ablest men, but the current set so strong, and the demagogues were so plausible, that the measure was carried, and in September the Government issued eight hundred million assignats, "solemnly declaring that in no case should the entire amount put in circulation exceed twelve hundred millions."

Great were the rejoicings on every side. Gold was to lose all value, as it was a superfluity, and the nation was committed to the policy of inflation. But the old cry of the "lack of a circulating medium" soon broke forth again. A hundred millions were issued under the plea of a want of small notes. On June 19, 1791, less than nine months after the former great issue, six hundred millions more were put in circulation. Next came depreciation of the currency, a loss of its purchasing power, and a rise in prices. Some said that this was due to ignorance in the rural districts, and the remedy proposed was "education of the people." M. Prudhomme's newspaper, however, declared that "coin will keep rising until the people have hung a broker." People naturally began to be alarmed, and to convert the paper into coin and hoard it up. This was regarded as criminal, and Marat asserted that death was the proper penalty for persons who thus hid their money.

But, after the first stimulus of these issues, business soon became depressed, trade stagnated, the manufactories were closed, and thousands of workmen were discharged. Uncertainty and fluctuation of values followed, speculation set in, and, in the language of Louis Blanc, "commerce was dead; betting took its place." "In the cities now arose a luxury and license which is a greater evil than the plundering which ministers to it. In the country the gambling spirit spread more and more; nor was this reckless and corrupt spirit confined to business-men; it began to break out in official circles; and public men who, a few years before, had been pure in motive, and above all probability of taint, became luxurious, reckless, cynical, and finally corrupt. . . .

"Even worse than this was the breaking down of morals in the country at large, resulting from the sudden building up of ostentatious wealth in a few large cities, and the gambling, speculative spirit fostered in the small towns and rural districts."

There was no stopping now. The artificial quickening had gradually run into a feverish activity, followed by intoxication, which had grown into a regular national debauch. Every issue of paper-money had made matters worse. But so deep was the infatuation that multitudes of people insisted that if there were only *enough* paper-money all would be well. On December 17, 1791, a new issue was ordered of three hundred millions more, and on April 30, 1792, still another three hundred millions were thrown out. The currency was now depreciated thirty per cent., and in July of the same year another three hundred millions were emitted. "Issue after issue followed at intervals of a few months until, on December 14, 1792, we have an official statement that thirty-four hundred millions had been put forth, of which six hundred millions had been burned, leaving in circulation twenty-eight hundred millions."

As articles of common consumption grew enormously dear, their holders became unwilling to sell them for the worthless currency with which France was flooded, and there then arose a demand that those who refused to make such exchanges should be punished with death. Laws were passed making the sales of goods compulsory at fixed prices in paper-money, which were, of course, inoperative. In 1793 there was an enactment forbidding the sale or exchange of specie for more than its nominal value in paper, under a penalty of six years' imprisonment in irons; and then twelve hundred millions more of the inflated currency was thrown out. "Toward the end of 1794 seven thousand million assignats were in circulation. By the end of May, 1795, the circulation was increased to ten thousand millions; at the end of June, to fourteen thousand millions; at the end of July, to sixteen thousand millions; and the value of one hundred francs in paper fell steadily first to four francs in gold, then to three, then to two and a half." The issues continued until, at the beginning of 1796, they amounted to over forty-five thousand million francs. One franc in gold was worth two hundred and eighty-eight francs in paper-money; sugar was five hundred francs a pound, and carriage-hire six thousand francs a day in the legal currency. Debts were, of course, now easily paid.

The madness continued, but its form was diversified. In 1796 "it was decreed that no more assignats be issued; instead of them it was decreed that a new paper-money, 'fully secured and as good as gold,' be issued, under the name of 'mandats.'" Choice public real estate was set apart to secure this money, but it speedily depreciated ninety-five per cent. It was decreed that those who refused to take it should be fined and sent to prison, and that those who even spoke against it should incur the same penalties. But the end at last came. On July 16, 1796, "it was decreed that all paper, mandats and assignats, should be taken at its real value, and that bargains might be made in whatever currency the people chose. The reign of paper-money in France was over. The twenty-five hundred million mandats went into the common heap of refuse with the previous thirty-six billion assignats. The whole vast issue was repudiated. The collapse had come at last; the whole nation was plunged into financial distress and debauchery from one end to the other."

We have given the bare skeleton

of facts contained in President White's pamphlet, but with nothing of his admirable analysis and exposition of the working of this great financial experiment. Let none fail to read and ponder the document. It is a lesson in one branch of political economy that our citizens cannot afford to neglect, and we are glad to be able to state that the publishers have issued an edition for universal circulation, as a campaign document needed at this time by both parties, and at a price so low that it may be distributed everywhere.

### *THE STATUE TO LIEBIG.*

It is proposed to raise a statue in Munich in honor of the illustrious chemist Liebig. No man better deserves such a tribute, for the claims of Liebig upon the appreciation and gratitude of the civilized world are unique and unrivaled. Starting from obscurity, he made his way by the pure force of genius alone, selecting his line of study even in boyhood, when he was snubbed by his teachers for the stupidity of his choice; he gave himself to chemistry early, unreservedly, with the enthusiasm of a vehement nature, and pursued it with indefatigable industry almost to the day of his death. He became a leader in this field in early life, became the acknowledged master amid a host of powerful competitors, and died the greatest chemist in Germany. The influence exerted by Liebig in the advancement of his favorite science it is hardly possible to over-estimate. His original investigations, each of which pushed forward the branch of inquiry to which it was devoted, are numbered by hundreds, so that, as Dr. Hoffman, in his recent eulogy, justly observes, "Were we to consider merely the vast number and incalculable importance of the chemical facts which he has established, we should have to proclaim him one of the greatest contributors to chemistry at large that ever have appeared, while of organic chemistry we could not hesitate to consider him the very source and fountain-head."

Liebig was a great experimenter, but that is not his highest title to eminence as a chemist. He enriched the science by new methods of analytic research, and invented the apparatus which gave a new impulse to organic investigations and made an epoch in organic chemistry, and he vastly enriched the science by varied and extensive laboratory researches. But it was not merely by these inquiries that he made the deepest impression upon the mind of the age. He was not only an experimenter, but a thinker; not only a chemist, but a philosopher; and it was in his grasp of principles and the establishment of general laws that we recognize his highest genius. Chemical analysis, the revision and correction of old processes, and the elucidation of new facts, are of course important and meritorious things, and in this field men of moderate ability may make valuable and permanent contributions to the progress of science. But it requires the insight of a higher genius to pierce through the multitudinous mass of isolated results, and bring out the principles that reduce them to order and bring them into living correlation with the general organism of scientific truth. This was the distinguishing character of Liebig's work in the chemical field. When he began his labors, physiological chemistry had hardly a foothold of recognition. The vital force was supreme in the realm of life, and was held to suspend and override all chemical and physical agencies. Liebig made a revolution by showing that a true physiological science can only be established by interpreting vital processes in the light of chemical and physical principles.

But the scientific fame of Liebig has a yet broader basis. He is the father of agricultural chemistry. Not only did he contribute largely to the elucidation of fundamental problems in this branch of study, and first give to it its recognition and status in the scientific world, but by the skill of his pen, his power of exposition and untiring industry, he aroused a popular interest in the subject which was felt through all the nations of civilization. Though a chemist, his name became as familiar in the households of this country as those of Newton and Shakespeare, while his work was recognized as having a practical beneficence that involved alike the prosperity of individuals, communities, and states. For, to give an impulse to agriculture, and to arouse the thought and quicken the intelligence of the agricultural classes, was to contribute essentially to the advancement of civilization itself. Whoever thinks that this is an exaggerated estimate of the claims and character of Prof. Liebig, may read with profit the admirable discourse of Dr. A. W. Hoffman, of the University of Berlin, on "The Life-Work of Liebig," delivered last year in London, and just published by Macmillan. It is not only a worthy tribute of a grateful pupil to his illustrious teacher, but it is a most admirable and discriminating estimate of the man in his relations to the progressive science of the age. We say, then, let all who believe in honoring the achievements of great men by erecting statues to their memories contribute toward the erection of this statue to Liebig. We ought to have one erected in the Central Park; but, if that be impracticable, let it be done in Munich. At the recent dinner given by the American Chemical Society to the foreign chemists connected with the Centennial Exhibition in Philadelphia, it was announced that Dr. Hoffman asks from this country a contribution of $2,500 to complete the work. Chemists, as a class, do not abound in this world's goods, but $1,000 was pledged for the purpose on the spot. Our enterprising and successful agricultural friends should have a hand in this work; and, if any are disposed to help it on, their contributions may be forwarded to Prof. E. N. Horsford, of Cambridge, or to Prof. C. F. Chandler, of New York, who will forward any funds that may be intrusted to them to the foreign committee who have the work in charge.

### *HAMILTON ON "SOCIAL SCIENCE."*

Mr. R. S. Hamilton, considering himself very badly treated in our notice of his book, made some time ago, pays us off in an article which appears in our pages this month. He lays it on to the editorial back without mercy, and nothing remains for us but to kiss the rod and resume the subject. Perhaps we are obtuse, but, having again looked over his volume, and our remarks upon it, in the light of what he now says, we are still unable to see that we have done him the injustice of which he complains.

Mr. Hamilton admits that our main accusation—and almost the only one—was, that his book is "old." Let us see, then, what ground he has for protesting against this position. Had he designated his volume by its secondary title, "A Review, Historical and Critical, of the Progress of Thought in Social Philosophy," which would have better described it, our criticism would have been uncalled for; but by putting it forth under the name of "The Present Status of Social Science" he invited attention to it as a report, up to date, on a highly-important and rapidly-developing subject. The Popular Science Monthly had but little interest in the historical and critical features of his work; but it was interested in its claim to inform its readers of the present attitude of a great science. Taking it up from this point of view—the view challenged by the author in the adoption of his title—we said it was "old." Not that we have the slightest objection to old books if they are good, or to old ideas if they are true, but only that it becomes sometimes necessary in science to discriminate between past and present conditions, although the past be quite modern. We did not, of course, consider the book old in the sense of the Assyrian inscriptions, but rather in the sense of a last year's almanac, which, although recent, still fails to indicate the present status of astronomical movements.

We said in our notice that the author "seemed to have but an obscure conception of social science," the implication of course being that his book is behind the age. He replies that "social science is a very large science," and may present different aspects to its different cultivators. But surely this need not imply obscurity in the conception of the science itself. Astronomy, geology, and biology, are very large sciences, and, no doubt, present different aspects to investigators in the same field, but this by no means necessitates vagueness or obscurity in the ideas of the aim, subject-matter, or methods, of either. There is common and well-determined work to be done in each, regardless of its extent.

But we were not left to inference in imputing to the author obscure conceptions upon the subject, for, according to him, no others are at present possible. In the first chapter of his book he says that "this important science has not yet attained to just, clear, and definite ideas as to its true and proper ends, and consequently it has not yet learned how even to begin its inquiries properly, how to direct its efforts, or systematize its observations. For this is precisely the present condition of social science." The obvious conclusion from this is, that as yet there is no such science. Its "status" is therefore in substance nothing, and in place nowhere, while the attempt to state it must needs be superfluous and impossible. This is a view that might have been held any time these thousands of years, and we think may be properly characterized as "old."

Mr. Hamilton labors to show that he was right in holding Herbert Spencer responsible for his "Social Statics," and denies that the modifications of opinion, which the author of that work declares he has undergone since its publication twenty-five years ago, are to be regarded as "important." Well, that depends upon the estimate he puts upon accuracy of representation. Mr. Hamilton's view of what is "important" in such cases will certainly not pass muster among scientific men, who are generally and properly emphatic in the assertion of their rights in this particular. They insist upon being judged only by the latest expression of their views, and chemists, physicists, and physiologists alike refuse to be bound by the old editions of their works. Mr. Spencer's modifications of opinion were held so important by himself that he strenuously resisted the republication of the book in this country when out of print in England; and, when overruled in this, he interposed a preface, warning his readers that it was no longer a truthful expression of his views. While not absolutely repudiating it, and while still adhering to its general conceptions, he yet declares that the theory which it enunciates has been so variously modified and further developed that he does not abide by its detailed applications. Several positions in the work are explicitly disavowed, and it is obvious that his changes of view affect its whole complexion. Mr. Hamilton attacked his chapter on "The Evanescence of Evil" with results satisfactory to himself; yet he could hardly fail to see that the argument of that chapter is merged in the great principle of Evolution, which has received its almost entire scientific development since the date of "Social Statics," while Mr. Spencer has been a leading student of that subject, and made it the foundation of his philosophy.

But Mr. Hamilton had before him Spencer's direct assertion that the doctrine underlying that part of the book (which contained the discussion on "The Evanescence of Evil") as there stated is but an adumbration of the view which he now holds. Is there no "important" difference between the dim foreshadowing of a principle and its distinct presentation with the limits and qualifications that result from years of research and reflection? Mr. Spencer declared, besides, that he could not revise "Social Statics" without great labor; and what does this imply but that the changes of the work would have to be extensive and important? Moreover, he has been long engaged upon the systematic extension of the subject to which his first book was dedicated, and he expresses the hope to set forth in due time "the developed conclusions of which 'Social Statics' must be regarded as a rough sketch."

A painter would not like to be critically judged by a rough sketch, and would consider it very important that judgment should be suspended until the work was finished—why not, then, a literary or a scientific artist? It was well enough, of course, for Mr. Hamilton to attack Spencer's old book, and riddle and ridicule it to his heart's content, if he thought it worth while. But, as his thesis was "the present status" of the great subject to which Spencer is devoting his life, he was bound in all fairness to let his readers know both how Mr. Spencer regarded his early treatise, and the import of his subsequent labors upon the same subject. Thirteen years before Mr. Hamilton's book was published Mr. Spencer had printed a programme giving a detailed outline of the course of thought by which alone, in his opinion, Sociology can be logically reached and scientifically unfolded. Mr. Spencer's position as a thinker was such as to command the high respect of eminent men, who indorsed his undertaking at the outset as one of great public importance. But of this Mr. Hamilton gives us no intelligible account, although Spencer's prospectus alone was a sufficient refutation of the statement that clear and definite ideas have not yet been reached regarding the true ends and methods of social science. The prominence that Mr. Hamilton gives in his own book to "Social Statics"—a work that Spencer, in elucidating the principles of social science, has left far behind—sufficiently shows that his treatment of the *science* of society is not up to date.

But, aside from the point of view we took in our very brief notice of Mr. Hamilton's book, we have no hesitation in saying it is a volume of much interest. It contains a good deal of valuable information and instructive discussion, "historical and critical, in relation to the progress of thought in social philosophy." It is only with regard to the social science which he professes to have triangulated, and fixed its latest position, that we think he is somewhat befogged—just sufficiently, perhaps, to entitle him to the perpetual presidency of the American Social Science Association.

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### *PROF. HUXLEY.*

This gentleman is evidently very much wanted in the United States. There is great anxiety to see him and hear him speak. The applications to secure lectures from him are numerous and urgent, the applicants being determined not to take no for an answer. It is a repetition of the experience with Tyndall four years ago, and the fact is significant, as showing that public interest in science is not a transient thing. In the case of Prof. Tyndall it was alleged by many that his brilliant experiments were the attraction, and that people went to his lectures impelled by the same motive that draws them to a pyrotechnic show. Of course, this was not true, but no such reason can be assigned for the desire to hear Prof. Huxley, as he never experiments. His chosen department of science is one of the most difficult, and the questions he discusses are profound. Undoubtedly in the great movement of thought in this age Prof. Huxley's topics are prominent, and many agencies have conspired to give them wide public interest; but we have to reckon Huxley's genius as one among the potent forces that in recent years have determined this course of public thought. Thus far we on this side know him only as a writer, and his remarkable powers in this respect are so well understood that nothing need be said about them here. But his accomplishments as a lecturer are quite equal to those displayed in his books. Said a distinguished English scientist the other day, who had come over as a Centennial juror: "And so Huxley is to be with you, and is going to lecture. Well, those who hear him will have a treat, for as a scientific lecturer he is unequaled. Next to John Bright I regard Huxley as the best orator in England; at any rate, in exposition, in elucidating a complex subject before a popular audience, we have no man to compare with him." Prof. Huxley's manner as a speaker is very quiet, and by those who like the vehement and demonstrative style it would be considered tame, but his discourse is clear, finished, deliberate, and strong. Nor, is it necessary that he should have a learned auditory to appreciate and enjoy his addresses. His command of his subject, of language and illustration, is so complete that he adapts himself with rare facility to the mental condition of his hearers. One of the most successful efforts we ever witnessed upon the platform was a lecture on physical geography given by Huxley to the working-men of London who filled to its last corner the large lecture-room of the Jermyn Street School of Mines. We had heard him before on ethnology at one of the "Friday evenings" of the Royal Institution before the *élite* of scientific London. It was an admirable discourse, and was listened to with the keenest attention and a lively pleasure, though how much of its success might be due to the cultivated character of the assemblage it was not then easy to say. But his Jermyn Street audience consisted of unlettered, hard-handed working-men, and yet there was not one among them that did not follow the speaker understandingly and with evidently as great enjoyment as the most cultured listeners. Prof. Huxley will be sure to please his American audiences, and, considering how much good he might do us, it is unfortunate that he cannot stay longer and speak in our chief cities. In the short course of lectures which he has consented to deliver in New York he will take up a subject which has long occupied him, upon which he is an authority, and which is certain to be treated in a manner that will gratify all who have the good fortune to listen to him. We announced last month that the lectures will take place on the 18th, 20th, and 22d of September, and that those desiring to secure seats could do so by registering their applications with D. Appleton & Co. The seats have been rapidly taken, and, as there is only a certain number of them, we must again remind those whom it may concern that when they are all bespoken no more can be had for love or money.

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## LITERARY NOTICES.

THE AMERICAN CYCLOPÆDIA: A Popular Dictionary of General Knowledge. Edited by GEORGE RIPLEY and CHARLES A. DANA. 16 vols., 13,314 pages. Price (cloth), $80.

THIS Cyclopædia, the first edition of which was completed in 1863, having proved its adaptation to the general wants by a very extensive sale, has now undergone complete revision, and, while preserving its well-known character, comes forth essentially a new work. Considerable portions of the original remain intact, where nothing has occurred to impair the accuracy of the statements; yet such are the activity of research and the vigilance of criticism in all departments of knowledge that but few subjects remain unaffected, and a large number of articles have required to be added or amplified, corrected or retrenched, so as to make the work thoroughly trustworthy, and to bring its multitudinous contents into proper symmetry and proportions. The changes in the new edition are marked. It has been freely illustrated throughout wherever engravings could help the text, and the scientific and political articles have been all rewritten, while the utmost pains have been taken to bring the endless details up to the latest standard of accuracy. Of course, the work is not free from imperfections, because knowledge itself is imperfect; but whatever could be done by the ability and experience of the editors, by their extensive corps of able contributors, and by the liberal expenditure of the publishers, to make the Cyclopædia worthy of public confidence, has certainly been accomplished. We say this without hesitation, and know something of that which we affirm. The office of the staff of editors of the "American Cyclopædia" adjoins our own, and for the past four years we have watched their proceedings with a lively interest and no little admiration. Having the advantage of a thorough apprenticeship in the preparation of the first edition, the editors were enabled to organize the work of revision in the completest manner from the start, and it has been carried on with unrelaxed assiduity, with a disciplined coöperation—an effectiveness of method and a conscientious caution that have brought the whole talent of the force into a focus, as it were, upon each page in its preparation for the press.

But in judging the merit of a cyclopædia we have to look further than this. Such a work may be a monument of careful labor, which is still misdirected. The question remains, What is its purpose, and how is its design fulfilled? There are cyclopædias upon all subjects, commerce, chemistry, agriculture, technology, fine art, engineering, and various other branches of knowledge; and they have special values, of course, for the cultivators of those branches, though very little value for general use. It is folly to expatiate upon the accuracy and fullness of a cyclopædia of antiquities, for example, to one who cares nothing about the subject. To a politician a cyclopædia of the physical sciences, however faithfully executed, would be but rubbish with which he would hardly cumber the shelves of his library. A cyclopædia is therefore to be judged primarily by its adaptation to the class for which it was prepared. The "American Cyclopædia," as a comprehensive and popular dictionary of general knowledge, appeals, not especially to this class or to that, but to intelligent people everywhere who desire a work of reference on all topics of current and general interest. More than any other work that has yet appeared, the "American Cyclopædia" is adapted to the daily uses and wants of American families. Its matter is chosen, harmonized, proportioned, illustrated, and put into literary form, we might almost say, with reference to their needs; and certainly, as a means of education in the family, its value is hardly to be over-estimated. It is a library of itself, in which the best information upon many thousands of subjects has been condensed so as to be quickly found at any moment when it is wanted. As books multiply until they become burdensome, and the pressure upon the time forbids their being read, we are more and more driven to the summaries of human knowledge, in which the husks of interminable talk are stripped away, and we are furnished with essential facts and compendious results. Hence the recent and growing popularity of encyclopedic literature. No agency of intellectual cultivation can be introduced into the family so direct and efficient in its quickening, enlarging influence upon the minds of the younger members of the family circle as a comprehensive, carefully-digested cyclopædia, convenient in form, for ready, habitual reference. It answers questions, solves difficulties, corrects errors, imparts varied and valuable information, and kindles the desire for mental cultivation. We say it does this; it does it in many instances, and would do it in many more if its importance were better understood. It must not be forgotten that a cyclopædia in a family, like a piano, must be used to be good for anything. It should be ready of access; and, instead of keeping it away in the library, or locking it up in a stately bookcase, it should be placed in a separate and open case in the room most commonly occupied by the family, and where the volumes can be reached by the very smallest amount of effort. By adopting this plan, a bright family will soon find the Cyclopædia among the first of daily necessities, and a source of constant pleasure and instruction. The publishers have anticipated this want of separate cases for their work, and supply them when desired; but any cabinet-maker will manufacture them at a trifling cost.

Darwiniana: Essays and Reviews pertaining to Darwinism. By Asa Gray. New York: D. Appleton & Co. Pp. 390. Price, $2.

The appearance of this volume will take many people by surprise. Although Prof. Gray is widely known in the world of science for his botanical researches, and in the world of education by his valuable text-books, but few are aware that he is a pronounced and unflinching Darwinian, or that he has been an able and vigorous defender of the doctrines that pass under this name, ever since they were first promulgated. He has written much upon this subject in various periodicals, but, caring only to let the arguments go for what they are worth, he has modestly withheld his name from the articles, the effect being that his position upon the question has not been a matter of notoriety. His contributions to the discussion are varied and valuable, and, as collected in the present volume, they will be seen to establish a new and unexpected claim upon the thinking world, which we are sure will be extensively felt and cordially acknowledged.

The history of what may be called the Darwinian discussion, in some of its aspects, is most curious and instructive. We complacently point back to those narrow and prejudiced times, from which we have happily escaped, when novel scientific opinions were rejected on the most frivolous and puerile grounds, urged by those who knew nothing whatever about them. But have we really much improved on those old practices, and do we even yet recognize that plain rule of common-sense, to leave the discussion of serious and difficult scientific questions to those who are competent to deal with them? Our times are eminent for just the contrary procedure. With all our vaunted liberalization, we dare not leave scientific questions to scientific men. In the history of the scientific controversies of the last three centuries there is no instance that will compare with this of "Darwinism," when the community has been so bewildered and misled by irrelevant and childish discussion on the part of grossly incompetent writers. The press has teemed with essays and books by men who were not only unfamiliar with the problems involved, and utterly ignorant of the sciences upon which their solution depends, but who had no intelligent conception even of the issues to be settled. Clergymen, lawyers, metaphysicians, *littérateurs*, having no acquaintance with natural history, and knowing nothing of the requirements, difficulties, and perplexities of scientific investigation, have rushed into the debate with a confidence and pretension contrasting strongly with the spirit of those who have given their lives to the study. Here comes another of these impudent and worthless performances, "A Critical Examination of some of the Principal Arguments for and against Darwinism," by James Maclaren, M. A., barrister-at-law; and what are the claims of this writer to attention? Why, he has written a book on the "History of the Currency;" and, with the mental equipment which such a work and his professional education imply, he assumes to deal with the greatest problem that has ever presented itself to the mind of man, a problem which belongs purely to science, and is engrossing the severest scrutiny of the most thoroughly disciplined scientific minds of the age.

Dr. Gray's book offers a refreshing contrast to this shallow strain of Darwinian literature. It comes of a direct, first-hand, and thoroughly familiar knowledge of the elements and objects which enter into the inquiry, and outweighs whole libraries of such productions as we have here referred to. The author says, in his preface: "If these papers are useful at all, it will be as showing how these new views of our day are regarded by a practical naturalist, versed in one department only (viz., botany), most interested in their bearings upon its special problems, one accustomed to direct and close dealing with the facts in hand, and disposed to rise from them only to the consideration of those general questions upon which they throw, or from which they receive, illustration." It is this characteristic which gives its eminent value to Dr. Gray's volume. On such a grave question, what we want to know is the intelligent opinion of men capable of forming an independent judgment, and a statement of the evidence on which they base their conclusions. The promulgation of Darwin's theory, in 1859, found Prof. Gray a trained student of the biological problems presented by the vegetable kingdom. With an extensive and accurate knowledge of plants, and a philosophical turn of thought which could not evade the question how the vast diversities of the plant world have been brought about, he had a solid preparation for judging of the claims of the "Origin of Species." Convinced of the total insufficiency of all previous theories upon the subject, he saw at once that Mr. Darwin's view was a great step forward in the pathway of science, resolving difficulties before insuperable, and promising to be of immense service in organizing existing knowledge, and in opening avenues of future investigation. The next year after the issue of the "Origin of Species," he published an elaborate article in the *American Journal of Science*, reviewing and interpreting it, and contrasting its doctrines with those advocated by Prof. Agassiz. This is the opening paper of the present volume, and was followed by a series of essays which appeared in various magazines, taking up many aspects of the subject, answering objections, elucidating obscurities, criticising adverse works, and contributing important additions to the general theory. These papers, as now printed together, not only illustrate the history of the controversy, and the progress of the discussion, but they form, perhaps, the fullest and most trustworthy exposition and illustration of what is to be properly understood by "Darwinism" that is to be found in our language. Of course, the work is not a systematic treatise upon the subject, but it covers the chief points that are of paramount interest, both to naturalists and to general readers.

But there is another feature of Dr. Gray's volume which will commend it, in even a higher degree, to large portions of the public. It gives earnest and prominent attention to the religious aspects of the question. Though a thorough-going Darwinian, Dr. Gray will not consent to hold his scientific opinions at the expense of his religious faith. Satisfied that the great principle of "Natural Selection" is a powerful working law of Nature, and holding to cardinal theological beliefs, he maintains that the conflict between them is not necessary, and that an enlightened interpretation of religious doctrine must bring it into harmony with the advanced scientific conclusions. Nor is it a mere semblance of faith that is to be harmonized with science by frittering away its essential character. Dr. Gray is out and out orthodox, and eminently sound in his theology. In his preface he says:

> "Then as to the natural theological questions which (owing to circumstances needless now to be recalled or explained) are here throughout brought into what most naturalists, and some other readers, may deem undue prominence, there are many who may be interested to know how these increasingly prevalent views and their tendencies are regarded by one who is scientifically, and in his own fashion, a Darwinian, philosophically a convinced theist, and religiously an acceptor of the 'creed commonly called the Nicene,' as the exponent of the Christian faith."

This portion of Dr. Gray's work is very able, and we think all candid religious readers will find it conclusive. To all those timid souls who are worried about the progress of science, and the danger that it will subvert the foundations of their faith, and who perplex themselves with the question whether a Darwinian can be a Christian, we recommend the dispassionate perusal of this volume. The subject is touched upon in various aspects in the different papers; but the last article, which is newly contributed to the volume, grapples with the gravest difficulty of the case, and is an elaborate discussion of "Evolutionary Teleology," or the doctrine of purpose and design in Nature as affected by the principle of "Natural Selection." Dr. Gray maintains with great force that, instead of being subverted by Darwinism, the doctrine of design is simply enlarged and seen to operate with a wider scope, and to stand upon a more comprehensive basis. He is by no means oblivious of the difficulties with which teleology is encompassed, and recognizes that it was the subject of powerful philosophical assault before Darwinism arose. But he sees also that the obstacles to the acceptance of the principle were due to the old ante-Darwinian views of the "Origin of Species." We can do no justice to this closely-reasoned essay by quotation from it, as it requires to be fully and carefully read to get a clear view of the author's position. A brief passage or two may, however, help to indicate it. Speaking of the contradiction involved in the old teleological interpretation of the origin of the organs and parts of living creatures, he says:

> "The error, as we suppose, lies in the combination of the principle of design with the hypothesis of the immutability and isolated creation of species. The latter hypothesis, in its nature improbable, has, on scientific grounds, become so far improbable that few, even of the anti-Darwinian naturalists, now hold to it; and, whatever may once have been its religious claims, it is at present a hindrance rather than a help to any just and consistent teleology.
>
> "By the adoption of the Darwinian hypothesis, or something like it, which we incline to favor, many of the difficulties are obviated, and others diminished. In the comprehensive and far-reaching teleology which may take the place of the former narrow conceptions, organs and even faculties, useless to the individual, find their explanation and reason of being. Either they have done service in the past or they may do service in the future. They may have been essentially useful in one way in a past species, and, though now functionless, they may be turned to useful account in some very different way hereafter. In botany several cases come to our mind which suggest such interpretation."

And again:

> "Darwinian teleology has the special advantage of accounting for the imperfections and failures as well as for successes. It not only accounts for them, but turns them to practical account. It explains the seeming waste as being part and parcel of a great economical process. Without the competing multitude, no struggle for life; and, without this, no natural selection and survival of the fittest, no continuous adaptation to changing surroundings, no diversification and improvement, leading from lower up to higher and nobler forms. So the most puzzling things of all to the old-school teleologists are the *principia* of the Darwinian. In this system the forms and species, in all their variety, are not mere ends in themselves, but the whole a series of means and ends, in the contemplation of which we may obtain higher and more comprehensive, and perhaps worthier, as well as more consistent, views of design in Nature than heretofore. At least, it would appear that in Darwinian evolution we may have a theory that accords with if it does not explain the principal facts, and a teleology that is free from the common objections.
>
> "But is it a teleology, or rather—to use the new-fangled term—a dysteleology? That depends upon how it is held. Darwinian evolution (whatever may be said of other kinds) is neither theistical nor non-theistical. Its relations to the question of design belong to the natural theologian, or, in the larger sense, to the philosopher. So long as the world lasts it will probably be open to any one to hold consistently, in the last resort, either of the two hypotheses, that of a divine mind or that of no divine mind. There is no way that we know of by which the alternative may be excluded. Viewed philosophically, the question only is, Which is the better supported hypothesis of the two?
>
> "We have only to say that the Darwinian system, as we understand it, coincides well with the theistic view of Nature. It not only acknowledges purpose (in the *Contemporary Reviewer's* sense), but builds upon it; and if purpose in this sense does not of itself imply design, it is certainly compatible with it, and suggestive of it. Difficult as it may be to conceive and impossible to demonstrate design in a whole of which the series of parts appear to be contingent, the alternative may be yet more difficult and less satisfactory. If all Nature is of a piece—as modern physical philosophy insists—then it seems clear that design must in some way, and in some sense, pervade the system, or be wholly absent from it. Of the alternatives, the predication of design—special, general, or universal, as the case may be—is most natural to the mind; while the exclusion of it throughout, because some utilities may happen, many adaptations may be contingent results, and no organic maladaptations could continue, runs counter to such analogies as we have to guide us, and leads to a conclusion which few men ever rested in."

It may be added that Dr. Gray's volume is eminently readable, and, though dealing with "solid" subjects, is far from "heavy." The author has a great deal more humor about him than the student of his botanical manuals would be led to suspect. But the readers of "Darwiniana" will find that he is not only capable of fun, but has given it a pretty free vent in these pages. He seems half inclined to apologize for this, saying in his preface:

> "If it be objected that some of these pages are written in a lightness of vein not quite congruous with the gravity of the subject and the

seriousness of its issues, the excuse must be that they were written with perfect freedom, most of them as anonymous contributions to popular journals, and that an argument may not be the less sound or an exposition less effective for being playful."

No apology, however, is needed, and it would be well if scientific writers having the capacity of humor would imitate the example of Dr. Gray in giving it freer expression in works designed for popular reading.

TRANSCENDENTALISM IN NEW ENGLAND: A HISTORY. By OCTAVIUS BROOKS FROTHINGHAM. G. P. Putnam's Sons. Pp. 395. Price, $2.50.

THE general purpose of the author in the preparation of this volume is thus happily stated by himself: "While we are gathering up for exhibition before other nations the results of a century of American life, with a purpose to show the issues thus far of our experiment in free institutions, it is fitting that some report should be made of the influences that have shaped the national mind, and determined in any important degree or respect its intellectual and moral character. A well-considered account of these influences would be of very great value to the student of history, the statesman, and philosopher, not merely as throwing light on our own social problem, but as illustrating the general law of human progress. This book is offered as a modest contribution to that knowledge."

The modern philosophic movement known as "transcendentalism," and the beginnings of which Mr. Frothingham traces to Germany, France, and England, has had a marked development in this country, and he has done a much-needed service to the students of the drifts and currents of modern thought by working out this historical delineation of it. No man was better prepared to do this useful work than Mr. Frothingham. By his wide, scholarly preparation, by his personal acquaintance with the leading characters who have had a share in it, by his sympathy with its influence, his observation of its results, and his attitude of an independant critic, he was qualified to deal with it on its various sides, and he has accordingly given us a book in a high degree readable and entertaining, instructive and valuable. Its merits as a study in philosophy are only equaled by the skill and attractiveness of its personal sketches of the men and women who have been prominent as representatives of transcendental thought. And, although Mr. Frothingham's reputation in the theological world will be regarded by many as dubious, yet his treatment of the historic bearings of transcendentalism upon religion is most suggestive, and may be read with profit by all interested in this class of questions.

THE LIFE AND LETTERS OF LORD MACAULAY. By G OTTO TREVELYAN. Harper & Brothers. Vol. I., pp. 416; Vol. II., pp. 406. Price, $5.

THIS biography has made a decided and unexpected impression upon the public mind; it is, in fact, a sort of revelation. Of Macaulay's outer life as essayist, historian, orator, and politician, everything was known, his career having been a conspicuous one. But as to his private life little was known except that he was supposed to be haughty and cold, and an everlasting talker, who harangued the company at dinner until everybody was tired of him. Very little was understood of his kindly and loving nature, and his tender and heroic devotion to his father's family from youth to age, as so admirably narrated in these volumes. We have not in a long time been so enchained by a biographical work as by this of Mr. Trevelyan. We have not space to give any analysis of it, or to make extracts from its pages, but it is proper that we should refer to one feature in Macaulay's education which the reviews thus far seen quite fail to notice. Macaulay went to the University of Cambridge and took early and powerfully to the purely literary aspects of culture. The sciences and mathematics he despised, and hated, and ridiculed. But mathematics is the great thing at Cambridge. Macaulay might have neglected and abused the physical sciences to almost any extent, but if he had paid a decent respect to mathematics all would have been well. As it was, he incurred the disapprobation of the authorities, and failed to reach the position he sought, and to which he was unquestionably entitled by the brilliancy of his scholarship. It was exactly in the field where he was strongest that the examiners plucked him. They admitted that his translations from the Latin and Greek were faithfully rendered, but objected to his ungraceful, bald, and inornate English. The biographer adds: "The real cause was beyond all doubt his utter neglect of the special study of the place: a liberty which Cambridge seldom allows to be taken with impunity even by her most favored sons." Universities are very human, after all.

It is, however, noteworthy and very significant that Macaulay changed his views in regard to some of these matters in maturer life. Mr. Trevelyan says, "He used to profess deep and lasting regret for his early repugnance to scientific subjects." And well may he have done so, for the sciences in which he was deficient had not only a direct bearing upon his work as a statesman and an historian, but they were rising every decade into increasing prominence in the world of philosophic thought. Had Macaulay given to some of the modern sciences even a fraction of that untiring attention and insatiate interest which he devoted to almost every form of literary rubbish, it might have made a wide difference in the conservation of his fame.

### The Logic of Chance. By J. Venn, M. A. New York: Macmillan. Pp. 500. Price, $3.75.

In a work with the above title one is prepared to find most of the illustration and demonstration mathematical. This, however, is not the case with the present treatise, for the understanding of which no knowledge of mathematics is required beyond the simple rules of arithmetic. The author's object is, to show what are the foundations and province of the theory of probability, with especial reference to its logical bearings and its application to moral and social science—a matter of strictly philosophical inquiry, though the problems which are met with in the application of the rules of probability often require a profound acquaintance with mathematics. In the first part of his work the author lays down what he calls the "physical foundations of the science of probability." According to him, in those classes of things with which probability is concerned, the fundamental conception which we have to bear in mind is that of a *series*. The individual members of a *series* seem to be governed by no law; but when we consider the result of a long succession we find a marked distinction: a kind of order begins gradually to emerge, and at last assumes a distinct aspect. In the second chapter the author has an able critique on certain fundamental postulates of Quetelet's system.

Part II. treats of the logical superstructure erected upon these physical foundations, and we have chapters entitled "Gradations of Belief," "The Rules of Inference in Probability," "The Rule of Succession," "Induction," "Causation and Design," "Material and Formal Logic," "Modality," "Method of Least Squares," and "Fallacies." The third part is devoted to considering various applications of the theory of probability. The principle of life and property insurance is explained; also the laws governing games of chance. Finally, there are chapters on the "Application of Probability to Testimony," "Credibility of Extraordinary Stories," and "Statistics as applied to Human Actions."

### Geological and Geographical Survey of Colorado and Adjacent Territory. 1874. By F. V. Hayden. Pp. 515, with Maps and Plates. Washington: Government Printing-Office.

The great amount of work performed by a United States Survey Expedition, during a field season, and the permanent value of such reports as that before us, will be understood from a brief statement of the method in which such surveys are conducted: 1. Such observations are made as will supply the data for a geological map, showing the distribution and extent of the formations which compose the surface of the region. A number of sections are examined, to ascertain how these formations lie upon one another, and to determine their relative ages and general paleontological relations. The extent and mode of occurrence of all economical products, as minerals, springs, etc., are noted, collections of rocks, fossils and the like, being made as far as possible. 2. The materials are collected for a map or representation of the surface features of the country, its streams, plains, mountains, cañons, etc., and this with all the accuracy that it is possible to give on a map of four miles to an inch, and in 200-foot contour-lines. Further, the general quality and distribution of timber, bottom, agricultural and unavailable lands are made the subject of investigation, while botanical, natural-history, and other specimens, are collected. The greater part of the volume treats of the geology, mineralogy, and mining industry of the region surveyed. Then there are separate reports on the Tertiary flora of the North American Lignitic, on ancient ruins in Southwestern Colorado, and on topography and geography.

VILLAGE COMMUNITIES IN THE EAST AND WEST. By SIR HENRY SUMNER MAINE. New York: Holt & Co. Pp. 425. Price, $3.50.

THE six lectures which give to this volume its leading title were first published in 1871, and have now reached a third edition. Their object is to trace the resemblances existing between the early stages of Western civilization and the existing status in many parts of India. Other scholars have shown the relations between modern European languages and the Sanskrit; the author's task is to point out the relations between the civil institutions of the East and West. Besides the lectures on village communities, the present volume contains sundry other papers, viz., one on the effects of observation of India on modern European thought, three addresses to the University of Calcutta, an essay on the theory of evidence, also one on Roman law and legal education.

COMMENCING with the July number, the *Penn Monthly* will hereafter be published for the Penn Monthly Association, by Jos. H. Coates & Co., Philadelphia. The editorship and ownership remain unchanged.

## PUBLICATIONS RECEIVED.

Practical Botany. By A. Koehler, M. D. New York: Holt & Co. Pp. 410, with Plates. Price, $3.00.

Report of the Milwaukee School Commissioners (1875). Pp. 307.

Hay-Fever. By G. M. Beard, M. D. New York: Harpers. Pp. 266. Price, $2.00.

Theory of Medical Science. By W. R. Dunham, M. D. Boston: James Campbell. Pp. 150. Price, $1.25.

Giannetto. By Lady Margaret Magendie. New York: Holt. Pp. 180. Price, $1.25.

*Archivos do Museu Nacional do Rio de Janeiro.* Quarterly. Pp. 30. Rio de Janeiro: Imprensa Industrial.

Smithsonian Collection, viz., Specific Heats, Specific Gravities, Expansion by Heat. By F. W. Clarke, S. B.

Geographical Variation among North American Mammals. By J. A. Allen. Pp. 40. From Report of Hayden's Survey.

Thought: Its Struggles and Failures. By L. S. Benson. New York: Serial Science Society. Pp. 32. Price, 15 cents.

Centennial Poem. By Mrs. A. W. Duchow. Sonora, California: *Tuolumne Independent* print.

Mountain Surveying: A Nebula Photometer; Comparison of Prismatic and Diffraction Spectra. By Prof. E. C. Pickering. From *American Journal of Science* and "Proceedings of the American Academy."

Determination of Baryum. By P. Schweitzer, Ph. D. Jefferson City: Regan & Carter. Pp. 36.

Report on Dermatology. By L. P. Yandell, Jr., M. D. Indianapolis: *Journal* print. Pp. 7.

Centres of Ancient Civilization in Central America. By Dr. C. H. Berendt. New York: D. Taylor, printer. Pp. 14.

Geometrical Chemistry. By H. Wurtz. New York: J. F. Trow & Son, printers. Pp. 73.

Journal of the American Society of Civil Engineers. May. Pp. 70.

Transactions of the Kansas Horticultural Society (1875). Topeka: Martin, printer. Pp. 267.

Some Disputed Points in Physiological Optics. By H. Hartshorne. Pp. 12.

# MISCELLANY.

**The Cruise of the "Challenger."**—*Nature*, for June 1st, gives an exceedingly interesting account of the voyage round the world recently completed by the Challenger. This voyage was undertaken chiefly for scientific purposes, the principal object being to "determine as far as possible the physical and biological conditions of the great ocean-basins of the Atlantic, the Southern Sea, and Pacific."

Important discoveries made during recent expeditions on the European border of the Atlantic and in the Mediterranean, by Dr. Carpenter, Mr. Gwyn Jeffries, and Prof. Wyville Thomson, stimulated a desire for further investigation, and this great voyage under direction of Prof. Thompson, as chief of the civilian staff, was inaugurated and carried through to a successful issue.

The ship left England on December 21, 1872, and returned to Spithead on May 24, 1876, having been absent a little less than three and a half years, and making a voyage of nearly 69,000 miles.

During this voyage 362 observing-stations were established, at each of which the depth and bottom temperature of the ocean were ascertained, and samples of the water, mud, and animals of the bottom, brought up for examination.

The direction and rate of currents were carefully studied, and "serial soundings" were made with special instruments to determine the temperatures at different depths. Upward of 50,000 meteorological observations were made during the first twelve months of the cruise.

The regular work of the expedition began at Teneriffe, from which point a line of soundings was carried across the Atlantic to the small island of Sombrero, a distance of 2,700 miles.

At 1,100 miles from Teneriffe, and 1,600 miles from Sombrero, bottom was found at 3,150 fathoms, which consisted of "perfectly smooth red clay, with scarcely a trace of organic matter," but at depths of only 2,200 fathoms the bottom was one mass of calcareous shells of foraminifera.

The red clay was found to be almost pure clay and a red oxide of iron with some manganese. This material is supposed by Prof. Thomson to be the residue or ash from decomposition of the shells. Experiments were made by Mr. Buchanan, of the staff of scientists, confirming this conclusion. He subjected globigerina ooze to the action of a weak acid, and found that after the carbonate of lime was removed there remained about one per cent. of a reddish mud, consisting of silica and alumina, and a red oxide of iron.

The globigerina shells were abundant at depths not exceeding 2,200 fathoms, but at greater depths a gray ooze occurred, the shells being in a state of decomposition; in deeper parts this disappeared, leaving the residuum of red clay.

This clay was found to be widely distributed in both the Atlantic and Pacific Oceans, and in many places contained concretions of the peroxide of manganese.

The specific gravity of ocean-water was carefully tested by Mr. Buchanan, and very unexpected results were obtained. The notion that the specific gravity increases with increase of depth seems unfounded, as it was ascertained to be greatest near the surface, diminishing to a depth of about 500 fathoms. From this downward it is nearly uniform.

Dredgings at great depths usually brought to the surface living organisms. At 3,150 fathoms (upward of three and a half miles) on the Atlantic cruise, only foraminifera were found, but other organisms were abundant at similar depths elsewhere.

By the serial temperatures taken in several places, it is evident that conditions exist which may greatly modify the distribution of the deep-sea fauna. Near Raine Island, not far from the entrance to Torres Straits, there was found at 2,650 fathoms, with bottom of red clay, a temperature of 35° Fahr. But it was also found that the same temperature occurred at a depth of only 1,300 fathoms. Here, then, the waters through 1,350 fathoms of depth, were of a uniform temperature. Over a wide area similar results were obtained, and the conclusion is, that this area, known as the Melanesian Sea, is so surrounded by a reef, rising to within 1,300 fathoms of the surface, that free communication of its waters with the outside ocean is prevented.

Animal life was found to be scarce in

this sea, but sufficient to show that it is "possible in the still bottom water, although such conditions in the Mediterranean do not seem to favor life."

The deepest water was found on the line from Admiralty Islands to Japan, one sounding giving the enormous depth of 4,575 fathoms, or five and a half miles. This is said to be the deepest trustworthy sounding yet made, excepting two by the Tuscarora off the east coast of Japan, where a depth 600 feet greater was found.

One of the results of this expedition has been to extend a knowledge of the fauna of the deep oceans, and the forthcoming work of Prof. Thomson will be brilliant with illustrations of new and beautiful forms.

The great voyage is divided into four sections. The first is from Sheerness, England, to the Cape of Good Hope, but by the very roundabout course of St. Thomas, Bermuda, Halifax, and St. Vincent. The second section is from the Cape of Good Hope to Hong-Kong by the way of Australia and the Polynesian Islands. The third section is from Hong-Kong to Valparaiso, touching at Japan, the Sandwich Islands, Tahiti, and Juan Fernandez. The fourth section is from Valparaiso to Sheerness, arriving on the 26th of May last.

**Recently-Discovered Fossils.**—In an appendix to the *American Journal of Science* for June, Prof. O. C. Marsh gives notices of a new sub-order of Pterosaurians, *Pteranodontia*, and of three new species of *Odontornithes*. The distinctive feature of the sub-order *Pteranodontia* is the *absence of teeth* (hence the name). The new genus *Pteranodon* is readily distinguished from any pterodactyls hitherto described by the cranial characters, which are well shown in a nearly perfect skull and portions of others in the Yale Museum. The cranium is very large, and the facial portion greatly elongated. There is a high sagittal crest which projects backward some distance beyond the occipital condyle. The maxillary bones are closely coössified with the premaxillary, and the whole forms a long, slender beak. There are no teeth or sockets for teeth in any part of the upper jaws, and the premaxillary shows some indications of having been incased in a horny covering. The lower jaws also are long and pointed in front, and entirely edentulous. In several other respects the jaws in this genus are more like those of birds than of any known reptiles.

From the same localities, and from the same geological horizon, the Upper Cretaceous of Western Kansas, which have yielded the specimens constituting the sub-order of edentulous Pterosaurians, come the remains of the *Odontornithes*, or birds with teeth, and the two doubtless lived together in the same region. The remains of one of these birds with teeth indicate a bird fully six feet in length from the apex of the bill to the end of the toes. The femur and the tibia resemble those of some modern diving-birds, but the toes are shorter and stouter.

**The Prehistoric Pig.**—In an essay on "The Prehistoric Pig of Britain," Prof. Rolleston arrives at the following conclusions: 1. The domesticated pig of pre-Roman times he refers to the wild variety of *Sus scrofa*. 2. The Indian wild-hog (*S. cristatus*) differs mainly by the retention of structural conformations which are only temporarily respresented in the European wild species. 3. Taking the changes which domestication produces into account, *S. Indicus* he conceives to be a modified *S. cristatus*, and not derived from *S. leucomystax*, or other species. 4. The skull of a wild-sow from the alluvium at Oxford possesses such a combination of characters as to cause the author to hesitate in accepting the Torfschwein (*S. scrofa*), variety *palustris* of Rütimeyer, as a distinct species. 5. Simplicity of third molars in a large skull of the Bornean pig (*S. barbatus*) has no value. 6. The *S. verrucosus*, in its tear and cheek bones, differs from the *S. barbatus*, and these peculiarities obtained in the old Irish "greyhound pig" figured by Richardson.

**Appropriation of Silica by Plants.**—Prof. P. B. Wilson, of Washington University, Baltimore, having, in a chemical examination of the ash of grasses, discovered that the silica contained in such ash differs essentially from silica reduced from natural silicates—that, in fact, it had been assimilated by the plant in the free state—determined to apply infusorial earth to land sown in wheat, and afterward with the microscope to search for the siliceous shields of diatomaceæ in the straw. Of course, if these were to be found occurring in the plant with the same forms which they have in the infusorial earth, it is plain that they must have been taken up by the plant and distributed through its system unaltered. The event fully justified this conclusion. The straw having been treated with nitric acid, the siliceous residuum was placed on the field of the microscope, and was seen to consist wholly of the siliceous shields of diatomaceæ, the same as found in the infusorial earth, excepting that the larger disks in their perfect form were absent—evidently because these disks were not sufficiently minute to enter the root-capillaries. The result of these investigations shows the necessity of finely-divided silica in the soil; also, that simple or compound silicates are useless as fertilizing agents.

**Forestry.**—The first of a series of papers on "European and American Forestry," now appearing in the *Penn Monthly*, contains a brief history of "Deforestation," or devastation of forests, in the Old World. The subject is one that nearly concerns the inhabitants of the United States, where the process of deforestation advances with unparalleled rapidity. Among the many instances quoted by the author of the evils consequent on the denudation of woodlands is that of Sicily, once the granary of Rome, now almost a waste from the effects of forest devastation. The island has scarcely a stream that lasts through the summer, and few perennial springs. The soil has suffered deplorably for want of sufficient irrigation. Greece, in common with Asia Minor, has been shorn of its original forests, and its characteristic feature is represented in steppes and unproductive barren wastes. Of Spain it may be said that at one time one-fifth of its surface was forest; now the proportion is only nine per cent. In different portions of the country noble forests still exist; but, on the whole, the destruction of the useful woods has been indiscriminate and improvident, and Spain, like all other countries, has suffered under the abuse of that universal law according to which soil and climate depend on the extent of forest-land.

**Air-Bags for raising Ships.**—Prof St. Claire, of Edinburgh University, in 1785 proposed the use of air-bags for the purpose of raising sunken ships. In 1864 air-bags were first practically applied for raising a steamer sunk in the lake of Boden; in this case the bags, owing to some defect, gave way. The Alexandrovsky system, perfected some ten years ago, has already rendered good service to the Government and commerce of Russia on several occasions. The bags adopted in the Russian Navy, as we learn from *Engineering*, are, when inflated, of cylindrical form, measuring twelve feet in diameter and twenty feet in length. They are composed of three layers of the thickest canvas saturated with India-rubber. Their lifting power averages sixty tons. In order to lift a vessel, several chains are drawn by divers under her bottom, and air-bags attached to the ends of each of them as near the ship's bottom as possible: the bags, being inflated by means of air-pumps, cause the ship to rise. Before pumping air into the bags, all the chains are connected in a transverse direction, so as to form one system, thus preventing the pairs of bags from sliding off from beneath the hull of the ship. As the vessel rises the surrounding water-pressure decreases, and the excess of air passes out through safety-valves.

**Night-Habits of Fish.**—Mr. W. Saville Kent had in the Manchester Aquarium a number of young herrings, which were so tame as readily to take their prepared food from the hand of a keeper. But a large number of the fishes were found dead each morning, a fact which seemed inexplicable, considering their quiet behavior during the day. A night inspection, however, revealed the cause of this rapid destruction. It was found that the nocturnal movements of the herring, at least in confinement, are altogether different from their movements in daylight. In the latter case, these movements are quiet and uniform, the fish swimming around their tank in one shoal and one continuous stream. At night, on the contrary, the shoal is entirely broken up, each fish taking an independent path, and darting from one side of the tank to the other with surprising agility. It was during these active nocturnal movements that the fish struck against the rockwork of the tank and came to an untimely end; this mortality, however, was soon arrested by placing a dim light over their tank, which illuminated the outline of the rockwork just sufficiently to enable them to recognize and avoid it. With this dim light the fish still retained their active habits, and it was noticeable that during these night-hours they were more than ordinarily alert for food, dashing vigorously at any entomostracan or other minute organism that passed through the water. This circumstance would seem to explain why "drift-net" fishing for herrings can be carried on successfully only at night, that being the time when the fish rise to the surface of the water to feed on the innumerable organisms that there abound.

**Prof. Mayer on Sound.**—Prof. Mayer, of the Stevens Institute of Technology, read at the late meeting of the Academy of Sciences a paper on the "Sensations produced by Concurrent and Rapidly-succeeding Sounds," a synopsis of which appears in the *Tribune*. The author showed how certain sounds extinguish the sensation of other sounds. The rule appears to be that, while low sounds cannot extinguish high ones, high sounds may obliterate low ones. He had been led to this course of observation by noticing that the click of a noisy clock was, at certain intervals, silenced if a watch was held to the ear. These intervals of silence, he ascertained, occurred when the sharp tick of the watch and the low click of the clock were simultaneous. Then by various and elaborate devices he satisfied himself, not only of the general fact, but as to what balancing of intensities was requisite. Prof. Mayer proceeded to demonstrate the application of the rule to musical sounds. This he made plain to the Academy by means of apparatus producing a certain low note from a wind-instrument simultaneously with the same note several octaves higher and of greater intensity. The high note killed, so to speak, the low one. But, on the other hand, a low note of great intensity was powerless to extinguish a faint high note: the high note utterly refused to be drowned by any volume of the lower sound.

**Ancient Condition of Great Salt Lake.**—According to Prof. G. K. Gilbert, of Wheeler's Expedition, the Great Salt Lake of Utah anciently had an outlet northward, the overflow being carried to the ocean by the Columbia River. But the Great Salt Lake was then a great inland sea, as is evidenced by the existence of an ancient beach 970 feet higher than the Great Salt Lake of to-day, and 700 feet higher than Sevier Lake. The subsequent changes of level are described as follows by Prof. Gilbert in the *American Journal of Science:* "From the upper beach the water slowly subsided by desiccation, recording its lingerings in a series of fainter shore-lines. When it had fallen to the level of the divide between the Sevier and Salt Lake Basins, it was separated into two unequal portions. In one of these the evaporation exceeded the inflow from rivers, and the subsidence continued; in the other the inflow exceeded the evaporation, and the surplus was discharged over the divide into the former portion, just as the surplus of Utah Lake is now discharged into Great Salt Lake. In the course of time, as the climate became drier, this overflow ceased, but not until it had carved a channel of some magnitude. This channel is crossed by the old overland stage-route, and is known as the Old River-Bed." It is the opinion of Prof. Gilbert that the humid climate which was marked by this inundation of Utah was preceded by one as arid as the present, and that the humidity was a phenomenon of the Glacial epoch. A fuller statement and discussion of the facts will appear in the forthcoming geological volume of the "Reports of Wheeler's Surveys."

**Spontaneous Hypnotism.**—A case of spontaneous hypnotism is described by Dr. Bouchut in *Les Mondes*. A little girl of ten had been apprenticed five months to the business of making waistcoats. One day, after a month of steady but not excessive work, and while sewing a button-hole, she became unconscious and slept for one hour. On awaking, she resumed her work, but with the same result. This hypnotism did not occur with any other kind of sewing. The case having now come under the notice of M. Bouchut, he gave the girl a button-hole to sew. She had hardly sewn three stitches when she sank from her chair on the ground, and fell fast asleep. M. Bouchut raised her up, and noted catalepsy of the arms and legs, dilatation of the pupil, slowness of pulse, and complete insensibility. She slept for three hours. Next day he made a similar experiment, when the girl slept only one hour. While no other kind of sewing could affect the girl in this way, M. Bouchut found that he could produce hypnotism by causing her to look intently on a silver pencil held at the distance of ten centimetres from the root of her nose. The case evidently was one of Braid's hypnotism, only occurring spontaneously, and not brought on by way of experiment.

**Periodic Movements of the Foliage of Plants.**—The *Abies Nordmanniana*, a coniferous tree now widely diffused on account of the elegant coloration of its leaves, appears to bear uniformly whitish foliage, when observed in the morning or toward evening, but when observed in the middle of the day the green tint seems general. The reason of this difference is found in the fact that the position of the leaves on the branch is different in the daytime from what it is at night; in the former case the leaves are spread out upon the branch and present their upper surface, producing the greenish aspect of the foliage; during the latter period, on the contrary, it is the lower or whitish surface that is presented to the observer. Thus there is a diurnal and a nocturnal position. As the day declines, the leaves, which at noon were horizontal, are seen gradually to erect themselves upon the branch, often becoming nearly perpendicular to it, and this movement of erection is accompanied by a movement of torsion in the basal part of the leaf, often traversing an arc of 90°.

**Treatment of Lunatics by Colored Light.**—Medical journals give an account of experiments recently made by Dr. Ponza, director of the lunatic asylum at Alessandria, Piedmont, to determine the influence of the solar rays on brain-diseases. Dr. Ponza, having communicated his views to Father Secchi, was encouraged to study the subject. In his letter to Dr. Ponza, the Roman astronomer expressed the opinion that the violet rays are of special importance. "Violet," he writes, "has something melancholy and depressive about it; perhaps violet light may calm the nervous excitement of maniacs." He then advises Dr. Ponza to perform his experiments in rooms with stained-glass windows, and with the walls painted of the same color as the glass panes. One patient, who had been affected with morbid taciturnity, became gay and affable after spending three hours in a red chamber; another, a maniac who refused all food, asked for breakfast after having staid twenty-four hours in the same red chamber. In a blue chamber a highly-excited madman became calm in one hour. A patient was made to pass the night in a violet chamber; on the following day he felt himself cured, and has been very well ever since.

**Unhealthy Trades.**—Among the lectures delivered by Dr. Richardson before the London Society of Arts, on "Unhealthy Trades," is one devoted to the "Industrial Diseases of Workers in Earthenware." He shows from the official statistics that potters are among the three sections of the population of England who represent the lowest vitality. The males of fifteen years and upward die at the rate of 38 per cent. above the males of all ages; and the commencement of this increased mortality is at the period when the men are approaching their prime of life, namely, at thirty-five years, and it extends onward to the end of life. Thus where in the general population 100 males of thirty-five years die, a proportion equal to 154 potters dies. For the four subsequent increments, namely, forty-five, fifty-five, sixty-five, and seventy-five years, for 100 deaths in the general male population, the deaths among male potters are proportionately 182, 181, 192, 141. The wages of the potters are good, and the labor not physically severe on healthy, fully-developed persons. The special diseases incident to this kind of employment are bronchitis with "potter's asthma," pulmonary consumption, and lead paralysis. Subsidiary to these are rheumatic affections and affections of the stomach. The special causes of disease are: variations of heat and cold, and constant inhalation of dust; these causes produce chronic bronchitis and asthma. The paralytic diseases are induced by lead; of these diseases the victims are the dippers and the women who assist them. "Could we," remarks Dr. Richardson, in conclusion, "relieve the earthenware manufacturers from the two grand causes of disease to which they are exposed, dust and lead, though some generations would be required in order to restore them, as a community, to perfect vitality, there is no reason why their death-rate should not, at once, be reduced to at least half its present excess, and the steady progress of their vital regeneration be immediately commenced."

**Effects of Cold on Milk.**—The effect of cold upon milk has been made a subject of experiment by M. Eugène Tisserand, who finds that if cow's milk is immediately, or soon after being drawn, placed in vessels at various temperatures between freezing-point and 90° Fahr., and the initial temperature maintained for twenty-four or thirty-six hours, the nearer the temperature of the milk is to freezing-point the more rapid is the collection of cream, the more considerable is the quantity of cream, the amount of butter is greater, and the skimmed milk, the butter, and the cheese, are of better quality. These facts, he believes, may be explained by Pasteur's observations on ferments. It is probable that the refrigeration arrests the development of living organisms and hinders the changes due to their growth. The facts stated indicate room for great improvement in the methods of storage and preservation of milk. To keep milk at its original quality, extreme cleanliness and a low temperature are absolutely necessary. In the north of Europe the value of cold is already recognized, and in warmer climates the need of its assistance is greater.

**Coal-Gas as a Fuel.**—The use of coal-gas in the place of gross fuel for the purposes of heating and cooking is rapidly coming into public favor in England. In this country the high price of gas is doubtless the principal reason why this most convenient form of fuel has not been more widely adopted, in the place of coal. The advantages of gas are manifold, and are clearly set forth in a paper read by Mr. John Wallace at a meeting of the London Society for the Promotion of Scientific Industry. First, we can absolutely control the amount of gas consumed and the degree of heat produced. In cooking, this control of the degree of heat is of the utmost importance: too quick or too slow a fire must result in bad cooking. Now, the heat of a coal-fire is very irregular, and is liable to be affected by so many circumstances that constant attention is required to keep it in the proper condition for delicate operations. Then, in point of cleanliness and facility of application, gas-stoves are far superior to coal-stoves. "The increasing cost of household labor," adds Mr. Wallace, "renders it highly probable that the same measure of success awaits the domestic application of gas as has already established the sewing-machine among our household gods. It is to be hoped that among the numberless schemes of gas-manufacture which have recently been made public we may soon be provided with a gas which shall be sufficiently cheap and plentiful to be used not only for lighting and heating in private dwellings, but also for trade and manufacturing purposes in workshop and warehouse."

**Toxic Action of Putrid Blood.**—The influence of various conditions upon the toxic property of blood has been investigated by V. Feltz, whose results, as communicated to the Paris Academy of Sciences, are briefly stated in the *Lancet*. He first determined the effects on a healthy dog. The injection of from one to three cubic centimetres caused all the symptoms of intense blood-poisoning in from three to eight days. Exposure to the air for periods of 24 to 96 hours made no difference in the toxic properties of the blood; exposure to compressed air for 24 to 144 hours was also without effect. Exposure to oxygen had different results, according to the time of exposure. Contact with oxygen for from 6 to 72 hours had no effect. Animals injected with blood which had been exposed to oxygen for 96 to 216 hours recovered after five or six days' illness. The result was the same with blood through which a continuous stream of oxygen was passed. A very similar effect was produced by exposure of the blood to a vacuum for many hours. A second series of experiments was to determine the influence of time on poisonous material. When the putrefied blood was kept so long that no living bodies could be discovered in it by microscopical examination, the same toxic effects were produced by its injection, but were less intense. Putrefied blood was then dried by slow exposure to the air, powdered, mixed with distilled water, and injected. The effects were not, as in the other cases, immediately manifest. After four to six days of incubation, the animals became ill; some died, others recovered. M. Feltz concludes that, as exposure to a vacuum and desiccation did not remove the toxic agent, it cannot be a gas; that activity on the part of the minute moving particles within it is not necessary for its septic effect; and that the development of bacteria, etc., in the blood of the animals injected, points to the germs of those bacteria as being the probable efficient means of the production of the poisonous effects.

**Ostrich-Farming.**—Ostrich-farming has within the past few years attained a remarkable development in South Africa. We present to our readers a few notes upon this new industry, taken from an address by Mr. P. L. Simmonds before the London Society of Arts. The climate in all parts of the Cape Colony is said to be alike favorable to the growth and production of the ostrich, and there are but few districts of the colony where this industry is not carried on. Mr. A. Douglas, of Hilton, appears to have been the first systematic breeder of ostriches in the Cape Colony. About eight years ago he bought a pair of birds, and subsequently added four more, making in all two cocks and four hens. By means of an incubator he succeeded in raising from these six birds 130 young ostriches in one season. The ostrich-farm of Mr. Kinnear, of West Beaufort, consists of eight acres of land, inclosed with fences. In this inclosure, which is sown with lucern, thirty ostriches are kept. There are two methods of obtaining the feathers, plucking them, and cutting them a little above the roots, which are removed two months afterward. Mr. Kinnear prefers the latter mode. The first plucking takes place when the bird is about eight months old, but the feathers are then not of much value. The operation is renewed every eight months. Three pluckings of birds in full plumage realized to Mr. Kinnear £240, or £120 per annum, that is, £8 per bird.

In the wild state, five female ostriches are often attached to one male, and they all lay their eggs in one nest, and sit on them in turn. Mr. Kinnear, however, only assigns one female to each male. They are coupled in July (the second month of winter), and commence laying in August, and continue laying for about six weeks, after which they sit till October. A month or six weeks later, they recommence to lay for about five weeks, provided the young brood are removed. In forming the nest—a large hole scraped in the sand—the male bird is most assiduous, and when all is ready the laying of the eggs commences. From fifteen to twenty eggs are laid and carefully arranged in the nest. The male bird usually sits by night, the female morning and evening; in the wild state the birds frequently leave the nest untended during the heat of the day.

Ostriches are, comparatively, inexpensive to keep, as during three-fourths of the year they require only a little artificial food, the grass produced on the farm being nearly sufficient for their maintenance; during the remaining fourth, they only need some supplemental supplies of green food, with a little Indian-corn. Each ostrich eats about twenty pounds of lucern a day.

**Culture of the Cochineal Cactus.**—The culture of the cochineal cactus was introduced into the Canary Islands in 1840. This plant, as indicated by its name, is the favorite food of the cochineal insect, whose body furnishes the well-known dyestuff cochineal. The culture developed rapidly, still for some years the supply of cochineal fell short of the demand. In 1848 prices varied from eleven to twelve francs per pound Spanish, the cost of production not exceeding 25 per cent. of this sum. A "cochineal mania" was the result, and all other crops had to give way before cochineal. Prices began to fall under the influence of this excessive production, and from 1860 to 1870 the cochineal sold for five to six francs, and there has been a steady decline ever since. In 1870 the price was four francs, in 1871 3.50 francs, in 1872 three francs, in 1873 2.50 francs. There is now a very general disposition to abandon this culture, and since 1872 the amount produced has been growing less from year to year. This decline is also, in a great measure, due to the introduction of new dyestuffs of mineral origin.

**Detection of Arsenic in Organic Matter.**—Dr. Armand Gautier proposes a new method for separating arsenic from animal matters, and for detecting its presence. By combining the sulphuric-acid and the nitric-acid processes he has obtained very satisfactory results, as regards both the rapidity of the operation and the exactness of the determinations. He first treats the matter supposed to contain arsenic with nitric acid, then with sulphuric acid, and finally with nitric acid again. By the first operation the organic substances are disaggregated; by the second they are destroyed very rapidly, and by the third, with the addition of more nitric acid, the last traces of organic matter are eliminated, while the formation of sulphide of arsenic is prevented. Having made a number of quantitative experiments, M. Gautier never met with a discrepancy amounting to so much as one-tenth of a milligramme between the amount of arsenic introduced and that found.

**Timidity of Birds.**—Dr. J. G. Cooper, in the *Naturalist*, comments on the "sociable and confiding disposition" of the birds of the Western United States, compared with the same species eastward. This difference, he remarks, has been noticed by several writers, but the reasons have so far been scarcely mentioned. According to the author, the chief reason is that in the West bird-collectors and idle boys are less numerous, while sportsmen find larger game so plenty that they do not waste ammunition on small birds. Besides this, the prevalence of prairies over most of the Western region makes any garden full of trees and shrubs a rare nursery for the woodland species, where they find more protection from hawks and weasels than in their native groves, while they may also levy a small contribution on the fruits in return for the insects they destroy, and their lively songs. In California, the poison intended for ground-squirrels has also destroyed millions of birds about the fields, and left them unhurt in gardens.

**Fattening Oysters.**—Salt oysters, on being transferred to fresh water, are "fattened" in the course of two or three days; if allowed to remain longer they become lean again, and are flavorless. Prof. Persifor Frazer, of the Academy of Natural Sciences of Philadelphia, holds that this change cannot be due to an increase of flesh, and attributes it rather to a simple distention of the tissues, owing to the admission into them of a greater quantity of fluid. During the oyster's period of growth on the sea-coast, its tissues are constantly saturated with the ocean-brine; on removing the animal to merely brackish or to fresh water, the conditions are at once favorable for osmose to be commenced. The fresher and less dense liquid without permeates inward more rapidly than the more saline and denser liquids within escape, and the effect is to swell the tissue, as a cow's bladder half filled with air and immersed in a vessel of hydrogen is swollen, or still more nearly like the swelling of a bladder half filled with copper sulphate when immersed in water. "It is worth while to inquire," adds Prof. Frazer, "whether means could not be devised to effect this fattening while yet not depriving the oyster of the salty flavor which is its chief charm to many consumers. Perhaps an immersion in concentrated brine for several days and its subsequent removal to ocean-water would suffice."

**"Shooting-Stars."**—We make a few selections from an interesting paper on "Shooting-Stars," by Prof. C. A. Young, published in the *Boston Journal of Chemistry*. These shooting-stars, he says, are very small, for the most part weighing certainly not more than a few grains, and possibly only some thousandths of a grain—mere particles or cloudlets of dust, which are traveling in space under the same laws as those which govern the motions of the planets and comets, and with a velocity as great. Their least velocity is more than thirty times that of a cannon-ball. When they encounter our atmosphere, this velocity is destroyed by the resistance, and, according to well-known laws, their energy of motion is converted into heat of intensity sufficient to render them incandescent, and even to dissipate any solid portions in vapor. Their numbers are very great. About forty per hour is a fair average for one station, or nearly one thousand each day. If the calculation is carried out for the whole earth, allowing that at each station all are observed which come within a circle two hundred miles in diameter, the total number reaching the earth daily is found to be about five million; indeed, Prof. Newton, who is perhaps the highest authority on this subject, sets the number still higher, at seven and a half million. A curious fact is, that the hourly numbers increase from sunset to sunrise by some fifty per cent. The reason is simply that in the evening we are, so to speak, behind the earth as it rushes through space, and see only those which overtake us; in the morning, on the other hand, we are in front, and see all we meet, as well as those we overtake.

The most remarkable discovery of recent times in respect to these bodies remains to be mentioned. It is found that in four well-marked cases the orbits of important meteoric swarms coincide exactly with the orbits of well-known comets; that the swarm of meteors follows in the wake of the comet and is somehow connected with it. The discovery dates from 1866, when Schiapparelli first proved the connection between the Leonids (November meteors) and Temple's comet. Since then the same thing has been shown of the Perseids, Lyrids, and Bielids.

**Cause of the Aurora.**—According to Groneman's hypothesis, an account of which is given in the *Academy*, there are streams of minute iron particles circulating around the sun like the well-known meteor-streams, and these, when they come near the earth, are attracted by its poles, and form filaments stretching out into space, in the same way as iron-filings, sprinkled on paper, arrange themselves in lines under the influence of a magnet underneath, each particle attracting the next by virtue of its induced magnetism. Groneman refers the phenomenon of the aurora to the ignition of this cosmical iron-dust in its passage through air, the distinction between this and an ordinary meteor-shower being that, on account of the filamentous arrangement of the particles in the direction of the dipping needle, streamers are formed, which by an effect of perspective appear to radiate from a point in that direction, and therefore nearly overhead. It is necessary to suppose that this meteor-stream is traveling nearly in the same direction as the earth, and Groneman enters into elaborate calculations to show that the velocity of the particles would not be too great to permit the magnetic attraction to form filaments of 200 miles in length.

**Dr. Roberts on Spontaneous Generation.**—Dr. William Roberts, of Owens College, Manchester, whose experiments were quoted by Dr. Bastian, in a recent communication, as favoring the doctrine of the spontaneous generation of bacteria, contradicts this interpretation of the results of his investigations. "On the contrary," writes Dr. Roberts, "the weight of my experiments is entirely against him" (Bastian), "and in favor of Pasteur's conclusions. It appears to me," he adds, "that the attitude of Dr. Bastian on the question of the origin of bacteria arises from what I may call the inverted significance which he attaches to the two contrasted results—barrenness or fertility—which follow after boiling an organic infusion. Throughout the controversy Dr. Bastian speaks of the barren tubes and flasks as 'failures,' or 'negative results;' and he evidently regards the fertile tubes and flasks as 'successful' experiments, having the force and authority of 'positive' results. The true view is just the reverse of this: it is the barren flask that has the character of a positive result. For what does the experimenter set himself to do in these experiments? He seeks to destroy, by boiling, all preëxisting bacteria in these infusions, and to leave unimpaired their powers of promoting the growth of bacteria. And it is found, in fact, that this latter quality is perfectly preserved in boiled infusions; for they breed bacteria with the utmost luxuriance when they are reinfected from an extraneous source. . . . When I take up one of the flasks or bulbs which have remained barren in my chamber for three or four years, though supplied with air (filtered through cotton-wool) and suitable heat, my wonder never ceases. Each one is a new experiment, every day repeated, and multiplied indefinitely; day after day I ask myself, 'Why does it not germinate?' I compare it to a field in spring not yet sown, but ready for the reception of the seed: for if I withdraw the plug of cotton-wool and admit the dust of the air, or introduce a drop of water, all is changed; in a few hours the stillness of years gives place to life and activity. I repeat, it is the fertile flask, and not the barren flask, that wears the complexion of a failure and of a negative result."

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## NOTES.

The American Association for the Advancement of Science meets this year at Buffalo, the sessions commencing August 23d. William B. Rogers, of Boston, is President; Charles A. Young, Dartmouth College, Vice-President Section A; E. S. Morse, Salem, Mass., Vice-President Section B; Thomas Mendenhall, Columbus, Ohio, General Secretary.

The Entomological Club of the American Association for the Advancement of Science will meet at Buffalo, N. Y., on the 22d of August, in quarters provided by the local committee of the Association. All interested in the subject of entomology are invited to attend, and to repair at first to the Tifft House for instructions.

The French Association for the Advancement of Science will hold its meetings this year at Clermont-Ferrand, commencing August 17th. The President of the Association is M. Dumas, of the Académie des Sciences.

The Agassiz Museum at Cambridge, Mass., has passed from the hands of the special board of trustees, and is now the property of Harvard College. Besides the real and personal property of the museum, the college comes into the possession of $115,000 in money, as also over $310,000 constituting the "Agassiz Memorial Fund."

The General Council of the British Association has fixed Wednesday, September 6th, as the date of opening this year's sessions. The place of meeting is the city of Glasgow. The authorities of the Glasgow University have tendered to the Association the free use of the commodious buildings situated in the western district of the city. A guarantee fund of £4,000 will be raised by the citizens of Glasgow; of this sum the city corporation gives £500. Sir R. Christison, who was elected President last year, has resigned on account of ill-health, and Dr. Andrews, Vice-President of Queen's College, Belfast, has been elected in his place.

A correspondent sends us an account of the passage of a brilliant meteor, unusually large and bright, over Northern Indiana, Northern Ohio, and Southwestern Michigan, on the evening of July 8th, at precisely nine o'clock. An observer at Elkhart, Indiana, says at that place it seemed almost exactly overhead, and its course began very near 61 Cygni, and ended about 5° south of Ursa Minor. The illumination was as bright as that of a full moon, and was of a greenish-yellow light. The whole pathway was visible for fifteen minutes, and for half an hour a bright, hazy spot, about 6° long and 3° wide, could be seen near the middle of the pathway. No sound accompanied the movement of the flaming body, and at last it disappeared in a sort of bluish light, very brilliant at first, but growing hazy, and finally disappearing. Judging from its height, if it descended to earth at all it must have fallen into Lake Michigan. The course of the body was as straight as an arrow, but its fiery trail very soon assumed the serpentine appearance that would naturally be caused by the atmospheric currents.

Died, recently, in London, at the age of seventy-five years, Edward Newman, F. L. S., F. Z. S., editor of the *Zoölogist* and the *Entomologist*, two serial publications which have attained considerable success among amateurs of entomology and natural history in England.

Three years ago there was founded at Boston a "Society to encourage Studies at Home." The number of students who received encouragement from the Society during the first year of its existence was 45, the second year 82, the third year 298. In making choice of studies to be pursued, 127 selected history, 118 English literature, 44 science, 36 art, 19 German, and 16 French.

Prof. C. Wyville Thomson, director of the scientific staff of the Challenger, has received the honor of knighthood from Queen Victoria.

A piece of telegraph-cable, the rubber covering of which had been pierced by grass, was exhibited at a meeting of the Bengal Asiatic Society; the efficiency of the cable was thus destroyed. The species of the grass, owing to its dried-up condition, could not be determined. It was suggested, as a probable explanation, that the seeds had become attached to the core when under water, and had afterward germinated when the core was stored.

Prof. Brudenell Carter, in an address on the "Relations of Ophthalmology to General Surgery," takes the ground that, while the growth of specialism in this department has given us improved operations and more dexterous operators, it has retarded investigation by diminishing the number of laborers in the field, and the opportunities of those laborers to study the facts from the standpoint of general pathology.

An Italian chemist, A. Casali, obtains a green pigment by calcining an intimate mixture of one part of bichromate of potash and three parts of baked gypsum, of the variety known as *scagliola*. The result is a grass-green mass which, on boiling with water, or mixing with dilute hydrochloric acid, leaves a fine powder of an intense green.

Reichardt recommends the use of the microscope in determining the mineral contents of potable water. On evaporating a few drops on a plate of glass, it is easy to distinguish carbonate and sulphate of lime and of magnesia, chloride of sodium, and nitrate of potash and of soda. C. Bischof further recommends the use of the same instrument for determining the organic substances contained in water.

A scheme has been recently devised for supplying London with an inflammable mixture of gases to replace coal. The new gas, "pyrogen," as it is called, is a mixture of nitrogen and carbonic oxide, three-fourths by weight consisting of the latter gas. The combustion temperature of pyrogen is stated to be 2,700° Cent., and for heating-purposes the flame of the burning gas is to be allowed to raise some good radiating substance to incandescence in an ordinary grate.

Felizet, of Elbeuf, having observed that in epidemics of foot-and-mouth disease no beast affected with cow-pox is ever stricken with the former disorder, vaccinated thirty oxen, and not one of the twenty-five beasts effectually vaccinated showed any sign of foot-and-mouth disease, even after living for months among animals largely affected with it.

Prof. Stanley Jevons is opposed to the project of assimilating the American dollar to the English pound sterling; he advocates, rather, assimilation to the five-franc piece. The partial accession of the United States to the franc system would, he says, immensely increase the motives for the English to accept it also, thus preparing the way for an international coinage.

For the purpose of photographing solar eclipses, Mr. Brothers, of the Royal Astronomical Society of London, suggests that at least three achromatic lenses of five or six feet focal length, corrected for the actinic rays, should be constructed, with all suitable apparatus, to be in readiness for use when required. The light of the corona, he adds, is sufficiently actinic to produce good pictures when an instrument of long focus is used—it is only a question of time in the exposure and accuracy in the adjustment of the driving-clock apparatus attached to the equatorial mounting.

The cruelty-to-animals bill, now under consideration in the British Parliament, provides that vivisection should only be performed with a view to the advancement of human knowledge, the prolongation of human life, or the alleviation of human suffering; that it must take place in a registered laboratory; that it must be performed by a person duly licensed; that the animals must be put under the influence of anæsthetics; and that, where pain would be prolonged after the anæsthetic effects had subsided, the animals should be killed.

In their last report, the Commissioners in Lunacy in England discourage the practice, which has grown to be quite general, of filling up the asylums with idiots, imbeciles, and eccentric or troublesome paupers, to the exclusion of the really insane, who need and are entitled to the skill, care, and attention, that asylums are intended to afford.

The Commission Supérieure of the Paris Exposition of 1878 has decided upon the general plan of the enterprise, and estimated the probable receipts. The expense is set down at 35,000,000 francs, and the receipts at 19,000,000; difference, 16,000,000 francs. To meet this deficit, the city of Paris will contribute 6,000,000 francs, and the state 10,000,000 francs. The buildings for the exposition will be erected in the Champ de Mars and in the Trocadero—localities situated on opposite banks of the river Seine. At first, it was proposed to widen temporarily the bridge known as Pont d'Iéna, but soon another project was entertained—that of erecting a new bridge forty metres in width. The question is yet under deliberation.

In the petroleum-mines of Alsace the miners test their safety-lamps in the following manner before going down the pits: At the bottom of an open jar is placed a small quantity of petroleum-spirit, the vapor of which, mingling with the air in the jar, forms an explosive mixture. The lamp is plunged into this mixture, and the slightest defect in the lamp is proved by an explosion.

GEORGE HENRY LEWES.

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# THE CONSTANTS OF COLOR.

By Prof. O. N. ROOD,
OF COLUMBIA COLLEGE.

THE tints produced by Nature and art are so manifold, often so vague and indefinite, so affected by their environment, or by the illumination under which they are seen, that at first it might well appear as though nothing about them were constant; as though they had no fixed properties which could be used in reducing them to order, and in arranging in a simple but vast series the immense multitude of which they consist.

Let us examine the matter more closely. We have seen that when a single set of waves acts on the eye a color-sensation is produced, which is perfectly well defined, and which can be indicated with precision by referring it to some portion of the spectrum. We have also found that, when waves of light having all possible lengths act on the eye simultaneously, the sensation of white is produced. Let us suppose that by the first method a definite color-sensation is generated, and afterward by the second method the sensation of white is added to it: white light is added to or mixed with colored light. This mixture may be accomplished with an ordinary spectroscope, by removing the scale from the scale-telescope, and replacing it by a vertical slit, as indicated in Fig. 1, which is a view from above. Then, if white light be allowed to enter this slit, it will be reflected from the surface of the prism into the observing-telescope, and we shall find that the spectrum is crossed by a vertical band of white light. By moving with the hand the scale-telescope, this white band may be made to travel slowly over the whole spectrum, and furnish us with a series of mixtures of white light with the various prismatic tints. (*See* Fig. 2.) The general effect of this proceeding will be to diminish the action of the colored light; the resultant light will indeed present to the eye more light, but it will appear paler; the color-element will begin to be pushed into the background. Conversely, if we now should subject our mixture of white and colored light to analysis by a second spectroscope, we should infallibly detect the presence of the white as well as of the colored light; or, if no white light were present, that would also be equally apparent.

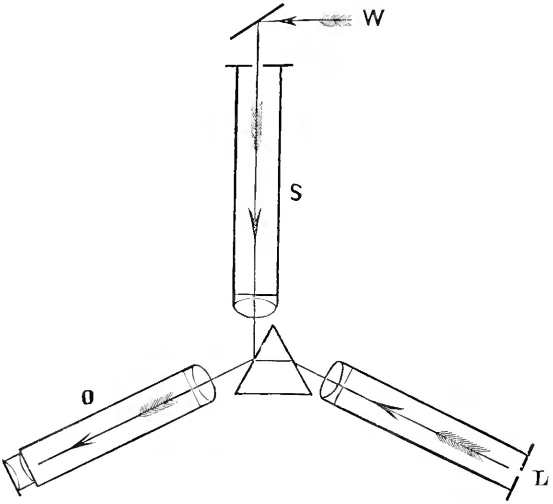

Fig. 1.—*O* is the observing-telescope; *S* the scale-telescope; *L* the source of light which furnishes the spectrum; *W* the white light which is projected on the spectrum.

Taking all this into consideration, it is evident that when a particular color is presented to us we can affirm that it is perfectly pure, viz., entirely free from white light; or that it contains mingled with it a larger or smaller proportion of this foreign element. This furnishes us with our first clew toward a classification of colors: our pure standard colors are to be those found in the spectrum; the colored light coming from the surfaces of natural objects, or from painted surfaces, we must compare with the tints of the spectrum. If this is done, in almost every case the presence of more or less white light will be detected; in the great majority of instances its preponderance over the colored light will be found quite marked. To illustrate by an example: If white paper be painted with vermilion, and compared with a solar spectrum, it will be found that it corresponds in general tone with a certain portion of the red space; but the two colors never match perfectly, that from the paper always appearing too pale. If, now, white light be added to the pure spectral tint, by reflecting a small amount of it into the observing-telescope, it will become possible to match the two colors, and, if we know what proportion of white light has been added, we can afterward say that the light reflected from the vermilion consists, for example, of eighty per cent. of red light from such a region of the spectrum, *plus* twenty per cent. of white light. If we set the amount of light reflected by white paper as 100, then a surface painted with "emerald-green" reflects about eight parts of white light; artificial ultramarine, two or three parts; red lead, seven or eight, etc. Some white light is always present; its general effect is to soften the color and reduce its action on the eye; when the proportion of white is very large, only a faint reminiscence of the original hue remains; we say the tint is greenish-gray, bluish-gray, or reddish-gray. The specific effects produced by the mixture of white with colored light will be considered in a future chapter; it is enough for us at present to have obtained an idea of one of the constants of color, viz., its purity. The same word, it may be observed, is often used by artists in an entirely different sense: they will remark of a painting that it is noticeable for the purity of its color, meaning only that the tints in it have no tendency to look dull or dirty, but not at all implying the absence of white or gray light.

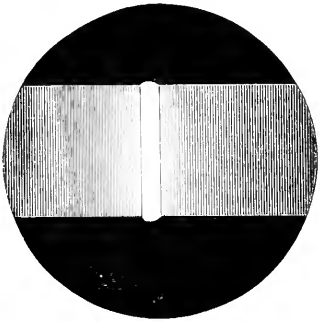

FIG. 2.—SPECTRUM CROSSED BY BAND OF SUPERIMPOSED WHITE LIGHT.

Next let us suppose that in our study of these matters we have presented to us for examination two colored surfaces, which we find reflect in both cases eight-tenths red light and two-tenths white light. In spite of this the tints may not match, one of them being much brighter than the other, containing, say, twice as much red light and twice as much white light; having, in other words, twice as great brightness or luminosity. The only mode of causing the tints to match will be to expose the darker-colored surface to a stronger light, or the brighter surface to one that is feebler. It is evident, then, that brightness or luminosity is one of the properties by which we can define color; it is our second color-constant. This word luminosity is also often used by artists in an entirely different sense, they calling color in a painting luminous simply because it recalls to the mind the impression of light, not because it actually reflects much light to the eye. The term bright color is sometimes used in a somewhat analogous sense, but the ideas are so totally different that there is little risk of confusion.

The practical determination of the second constant is possible in a great many cases; it presents itself always in the shape of a rather troublesome photometric problem, capable of a more or less accurate solution. The relative brightness of the colors of the solar spectrum is one of the most interesting of these problems, as its solution would serve to give some idea of the relative brightness of the colors, which, taken together, constitute white light. Quite recently a set of measurements were made in different regions of the spectrum by Vierordt, who denoted the points measured by the fixed lines, as is usual in such studies.[1] The following table will serve to give an idea of his results:

| Color. | Degree of Luminosity. |
|---|---|
| Dark red | 800 |
| Red | 4,930 |
| Red, slightly orange | 11,000 |
| Orange red | 27,730 |
| Orange | 69,850 |
| Yellow | 78,910 |
| Green | 30,330 |
| Cyan blue | 11,000 |
| Blue | 4,930 |
| Ultramarine blue | 906 |
| Violet | 359 |
| " | 131 |
| " | 58 |
| " | 9 |

These measurements were made on a spectrum obtained by a glass prism, which, as has been mentioned in a previous chapter, contracts the red, orange, and yellow spaces unduly, and hence increases their illumination disproportionately. It is to be hoped that a corresponding set of measurements will soon be made on the normal spectrum, furnished by a ruled plate. If we should multiply the luminosity of the colors in either kind of spectrum by their extent or areas, we should obtain measures of the relative amounts of these several tints in white light.

By the simple method of rotating disks we can very roughly determine the second constant in the case of a colored surface, for example, of paper tinted with vermilion. A circular disk, about six inches in diameter, is cut from the paper, and placed on a rotation apparatus, as indicated in Fig. 3. On the same axis is fastened a double disk of black-and-white paper, so arranged that the proportions of black-and-white can be varied at will. When the whole is set in rapid rotation, the color of the vermilion paper will of course not

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[1] C. Vierordt, *Poggendorf's Annalen*, Band cxxxvii., S. 200.

be altered; but the black-and-white will blend into a gray. This gray can be altered in its brightness till it *seems* about as luminous as the red. If we find, for example, that with the disk three-quarters black and one-quarter white an equality appears to be established, we conclude that the luminosity of our red surface is twenty-five per cent. of that of white paper. This is of course based on the supposition that the black paper reflects no light; it actually reflects from two to five per cent., the reflecting power of white paper being put at 100. The results thus obtained are always inexact, and the same observer will often obtain different results on different days, though those of a single day may agree pretty well among themselves. In the appendix to this chapter, a peculiar photometer will be described, which has been contrived by the author for the purpose of comparing more accurately together the relative luminosity of different colored surfaces, or that of colored and white surfaces.

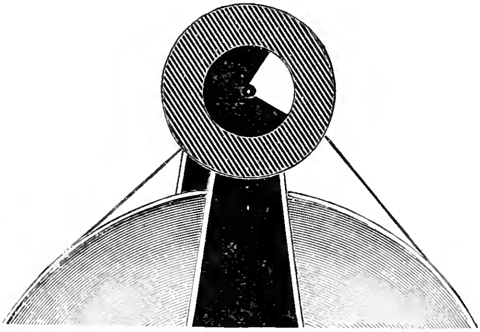

FIG. 3.—COLORED DISK WITH SMALL BLACK-AND-WHITE DISK.

FIG. 4.—COLORED DISK WITH SMALL BLACK-AND-WHITE DISK IN ROTATION.

But to resume our search for color-constants. We may meet with two portions of colored light, having the same degree of purity and the same apparent brightness, which nevertheless appear to the eye totally different; one may excite the sensation of blue, the other that of red; we say the *tones* are entirely different. The *tone* of the color is, then, our third and last constant, or, as the physicist would say, the degree of refrangibility, or the wave-length of the light. It has in a previous chapter been shown that the spectrum offers all possible tones except the purples, well arranged in an orderly series; and the purples themselves can be produced with some trouble, by causing the blue or violet of the spectrum to mingle in certain proportions with the red. Rutherford's automatic six-prism spectroscope can very conveniently be employed for the determination of the tone. (*See* Fig. 5.) A peculiar eye-piece is to be used, which isolates a little slice of the spectrum in its upper half, as indicated in Fig. 6. In the lower half of the field the fixed lines are seen, and the tone selected as matching the color under examination can be located by their aid. Afterward, if it is considered desirable, white light can be added to the spectral tint, till it is subdued sufficiently to render exact comparison possible.

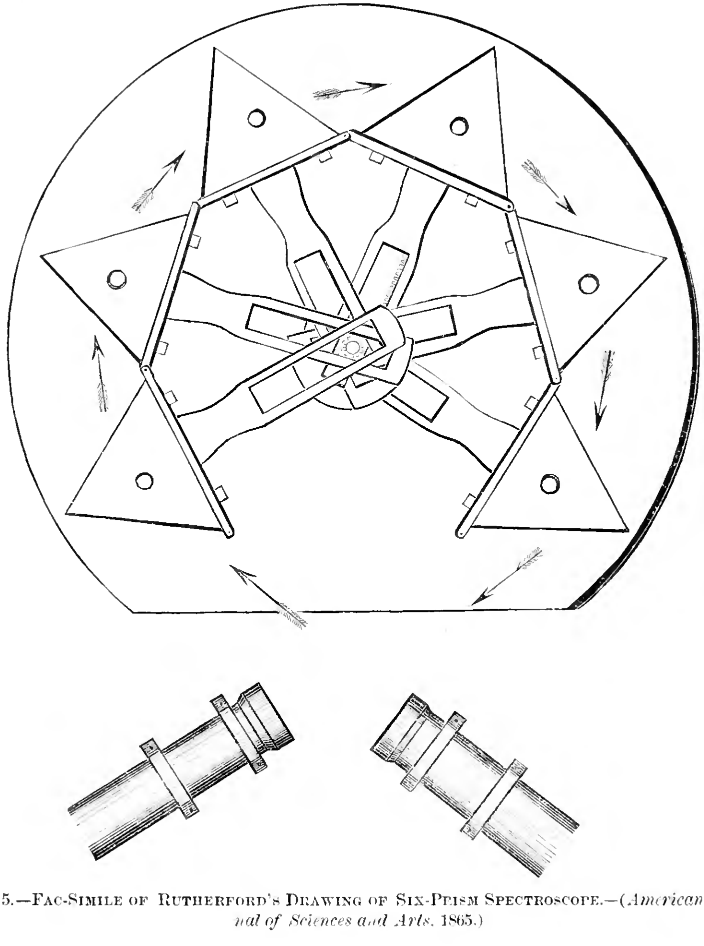

Fig. 5.—Fac-Simile of Rutherford's Drawing of Six-Prism Spectroscope.—(*American Journal of Sciences and Arts*, 1865.)

The experimental determination of the color-constants is beset with a considerable amount of difficulty, even in the simplest cases, such as cardboards covered with pigments. The best mode of proceeding appears to be to call the luminosity of white cardboard 100, and then to determine photometrically the comparative luminosity of the colored cardboards. The measurement of the amount of white light reflected along with the colored is still more troublesome, and the result likely to be somewhat less exact, while the determination of the tone, or third constant, is moderately easy under favorable circumstances. One of the uses of such determinations is the production of a set of standard colored disks with known constants, which can afterward be combined with each other, as well as with standard black or white disks, so as to generate at will, with ease and certainty, an immense number of tints whose constants will be known. If we make a record of the constants involved in such experiments, we can afterward reproduce the tints just as they originally were, or alter them to any desirable extent. To carry out the letter of this it will of course be necessary to view the standard disks under similar illuminations at different times, a point which can be secured with the aid of the photometer above referred to. The standard disks can also be used for building up a set of standard charts, containing a vast variety of tints of known composition, arranged methodically with regard to purity, luminosity, and tone. These matters will be considered at some length in a separate chapter, and are now only hinted at as a justification for the trouble we have been at in defining the constants of color.

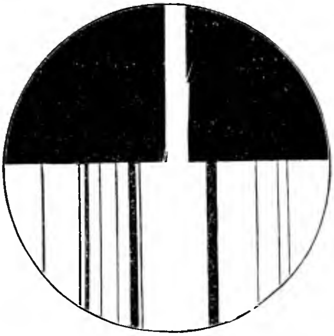

Fig. 6.—Eye-Piece for isolating the Tints of the Spectrum.

There is another point to be touched on in this connection. One of the most noticeable things about colors is their difference in *intensity*. Colors are intense when they excel both in purity and brightness; for it is quite evident that, however pure the colored light may be, it still will produce very little effect on the eye if its total quantity be small; and, on the other hand, it is plain that its action on the same organ will not be considerable if it is diluted with much white light. Purity and brightness, or luminosity, are, then, the factors on which intensity depends. We shall see hereafter that this is strictly true only within certain limits, and that an inordinate increase of luminosity is attended with a loss of intensity of hue.

Having defined the three constants of color, it will be interesting to inquire into the sensitiveness of the eye in these directions. This subject has lately been studied with care by Aubert, who made an extensive set of observations with the aid of colored disks.[1] It was

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[1] Aubert, "Physiologie der Netzhaut," Breslau, 1865.

found that the addition of one part of white light to 360 parts of pure colored light produced a change which was perceptible to the eye; smaller amounts failed to bring about this result. It was also ascertained that mingling pure colored light with from 120 to 180 parts of white light caused it to become invisible, the hue being no longer distinguishable from white. Differences in luminosity as small as $\frac{1}{120}$ to $\frac{1}{180}$ could under favorable circumstances be perceived. It hence followed that irregularities in the illumination or distribution of pigment over a surface, which were smaller than $\frac{1}{180}$ of the total amount of light reflected, could no longer be noticed by the eye. Experiments with red, orange, and blue disks were made on the sensitiveness of the eye to changes of tone or refrangibility; thus the combination of the blue disk with a minute portion of the red disk altered its hue by moving it a little toward violet; on reversing the case, or adding a little blue to the red disk, the tone of the latter moved in the direction of purple. Similar combinations were made with the other disks. Aubert ascertained, in this way, that recognizable changes of tone could be produced by the addition of quantities of colored light as small as from $\frac{1}{100}$ to $\frac{1}{300}$ of the total amount of light involved. From such data he calculated that in a solar spectrum at least 1,000 distinguishable tones are visible. But we can still recognize these tones when the light producing them is subjected to considerable variation in brightness. Let us limit ourselves to 1,000 slight variations, which we can produce by gradually increasing the brightness of our spectrum, till it finally is ten times as luminous as it originally was. This will furnish us with a million tones, differing perceptibly from each other. If each of these tones is again varied 300 times, by the addition of different quantities of white light, it carries up the number of hues we are able to distinguish as high as 300,000,000. In this calculation no account is taken of the purples, or of colors which are very bright or very faint, or mixed with very much white light. For these it will hardly be extravagant to demand another 100,000,000; we reach thus the astonishing conclusion that the human eye under favorable circumstances is able to distinguish as many as 400,000,000 different hues!

# MODERN PHILOSOPHERS ON THE PROBABLE AGE OF THE WORLD.[1]

A SHORT time ago Sir William Thomson took occasion, at a meeting of the Geological Society of Glasgow, to make a somewhat startling statement. He said that the tendency of British popular geology was, at the time he spoke, in direct opposition to the principles of natural philosophy.

So strong an opinion expressed by the man who is, perhaps, foremost in this country in applied mathematics and natural science, naturally attracted great attention, and it is not too much to say that in the six years which have since elapsed a very great change has taken place in the views of those best able to form an opinion on the subject of Sir William Thomson's animadversions.

Whether or not we are correct in saying that such a change has actually taken place in educated public opinion, it is the object of this paper to show; but we may at least affirm at the outset, without fear of contradiction, that a very smart conflict has been raging on the subject in the scientific world. The opposing forces are the geologists and the mathematicians. There has been hard hitting on both sides, and no quarter given. Of late the mathematicians have brought up their reserve, a contingent of natural philosophers, who have done good service. The latest intelligence from the seat of war speaks of a suspension of hostilities. The mathematicians will make no concessions, but the geologists appear likely to abate somewhat of their high demands. There is even some talk of an amalgamation of the opposing armies. In plain English, there has been a dispute as to the age of the world. Geologists declared that the centuries of its duration could only be denoted by an array of figures so large as to paralyze the reasoning faculties and convey no definite impression to the mind. Other branches of science have shown cause for attributing to the solar system a limit of duration, vast indeed, but not absolutely inconceivable.

To those whose interest in such matters is literary rather than

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[1] 1. "Lectures on some Recent Advances in Physical Science." By Prof. P. G. Tait, Professor of Natural Philosophy in the University of Edinburgh. 1876.
2. "On Geological Dynamics." By Sir William Thomson, LL. D., F. R. S. "Transactions of the Geological Society of Glasgow," 1869.
3. "On Geological Time." By Sir William Thomson, LL. D. "Transactions of the Geological Society of Glasgow." 1868.
4. "Sur le Ralentissement du Mouvement de Rotation de la Terre." Par M. Delaunay. Paris, 1866.
5. "Climate and Time." By James Croll. "H. M. Geological Survey of Scotland." London, 1875.
6. "Principles of Geology." By Sir Charles Lyell. Fourteenth edition. London, 1875.

scientific, the progress of such a controversy is often very entertaining. It is true that the actual battles take place in places beyond our ken, generally at meetings of scientific societies, where the orators have it all their own way and confound their adversaries—till the opposition society meets. But though the philosophers retire for fighting purposes, and do battle in the clouds with weapons, phrases, and formulæ, that we cannot understand, they always come down again to earth to proclaim their victories or palliate their defeats. Once they come down, and we catch them with pens in their hands, the outsiders have their turn.

It is not, however, in the great books of Darwin, Huxley, Lyell, Helmholtz, Tait, or Thomson, that we may seek food for amusement. In these works every thought is in full dress and every phrase decorous. But there is another sort of literature in which we see the great men, so to speak, with their coats off. The "Proceedings" of the learned societies where the real fighting goes on are full of entertainment. Students of human nature need no further proof that, though every man may not be a philosopher, every philosopher is certainly a man. With what frank enjoyment they fight! With what irony—what sarcasm they annihilate their foes! It must, however, be confessed that sarcasm is not, as a rule, the strong point of the learned. The editor of a northern newspaper of our acquaintance was one day speaking in terms of praise of his sub-editor: "The brilliancy of yon young man," said he, "is surprising; the facility with which he jokes amazes me. I, myself, am in the habit of joking, but I joke with difficulty." We have observed the same peculiarity among other learned persons. They joke, but not with ease.

Most of the books which we have prefixed to this paper contain their authors' thoughts polished *ad unguem*. It would not be fair to judge of the opinions of the scientific persons we quote by any other standard than that which they have themselves carefully prepared; but yet we cannot refrain from entertaining a preference for the rough-and-ready, hard-hitting pamphlets, lectures, "proceedings," inaugural addresses, and the like, from which, almost without exception, these works have been compiled. For example, Mr. Croll's work on "Climate and Time" is everything which a scientific work should be that requires deep research and laborious thought, combined with the boldest generalization; but it is a digest of some five or six and thirty papers contributed to scientific magazines and periodicals during several years. Mr. Croll gives a list of his papers at the end of his volume. But though it is most convenient to see the whole before us at a glance, and to have them all under our hand or on the library-shelf, yet we acknowledge that while thinking over Mr. Croll's volume, for the purposes of this review, we found ourselves again and again going back to the pages of the *Reader* and the *Philosophical Magazine*, in which we first made acquaintance with them. It may be prejudice in favor of old acquaintances, but we liked them better before. Digressions, perhaps, are cut out; some little rash speculation quietly withdrawn; some hit at an opponent suppressed; but they do not always command the same ready assent, or appear so interesting as they did in their old form.

These remarks do not apply to Prof. Tait. His lectures now before us, from their nature, belong to the class of composition for which we avow our predilection. They were delivered *extempore* to a scientific audience, and printed from short-hand notes. They lose nothing of their vigor, to use an expression of Lord Macaulay, by translation out of English into Johnsonese. We are allowed to seize the thought in the making, and, if it loses anything in grace, the loss is more than counterbalanced by power.

Those who wish thoroughly to understand the subject of this paper should study Prof. Tait's lectures on the souces of energy, and the transformation of one sort of energy into another. Matthew Arnold's phrase, "let the mind play freely round" any set of facts of which you may become possessed, often recurs to the mind on reading these papers. There is a rugged strength about Prof. Tait's *extempore* addresses, which taken together with their encyclopedic range, and the grim humor in which the professor delights, makes them very fascinating. They have another advantage. Men not professionally scientific find themselves constantly at a loss how to keep up with the rapid advance which has characterized recent years. One has hardly mastered a theory when it becomes obsolete. But in Prof. Tait we have a reporter of the very newest and freshest additions to scientific thought in England and on the Continent, with the additional advantage of annotations and explanations by one of the most trustworthy guides of our time.

We propose to discuss the books and papers whose titles are prefixed to this article, in so far as they throw fresh light on the probable length of time during which the solar system may be supposed to have existed. It is but in recent times that any materials have been amassed for forming an opinion on the subject. Before the end of the last century geology hardly existed as a science; an inquiry as to the age of the world would have been unhesitatingly answered by the assertion that the earth was created in six days, 4,004 years before the birth of Christ. Though further research has shown that the sacred text bears no such interpretation, those copies of the "Authorized Version of the Bible" which are enriched with notes and marginal references still keep up the formal assertion.

A story is told in Brydone's "Tour in Sicily" which will serve to recall the state of public opinion on the subject of chronology at the end of the last century. The Canonico Recupero, a Sicilian priest, was Brydone's guide when he explored Mount Etna. Recupero (who afterward wrote a history of his native mountain) told the traveler that he had been vastly embarrassed by the discovery that many strata of lava, each covered deeply with earth, overlaid each other on the mountain-side. "Moses," said he, "hangs like a dead weight upon me, for I have not the conscience to make the mountain so young as that prophet makes the world." "The bishop," adds Brydone, "who is strenuously orthodox—for it is an excellent see—has warned him to be on his guard, and not to pretend to be a better historian than Moses."

The worthy Bishop of Catania was not alone in his views. Nearer home it was the generally-received opinion that to doubt the literal accuracy of the chronology supposed to be involved in the Mosaic account was a grave impiety. The poet Cowper, mildest of men, became fiercely satirical under the provocation of geology. Though few people read "The Task" nowadays, the lines will no doubt be remembered:

> " . . . . Some drill and bore
> The solid earth, and from the strata there
> Extract a register by which we learn
> That He who made it, and revealed its date
> To Moses, was mistaken in its age."

Fortunately, it is no longer considered impious to try and "extract a register" from the earth. Those who were inclined to be afraid that the Mosaic record would be discredited have long since laid aside their fears. It has been found that, far from being upset by scientific inquiry, the Bible account of the Creation accords in a very remarkable manner with modern discoveries; and long before Max Müller put the feeling into words, it was felt that only "by treating our own sacred books with neither more nor less mercy than the sacred books of other nations, they could retain their position and influence."

When once the plunge was made, it was soon found, as might have been expected, that the fault was not in the oracle, but in the interpretation; and it is very remarkable in how many and unexpected directions the testimony of Moses has been strengthened by the criticism, not always friendly, which it has received. Of course, when the anciently-accepted date of the Creation was proved to be incorrect, and chronology was, as it were, thrown open to the public, there was nothing to prevent philosophers from allowing the freest scope to their imagination. In proportion as the six thousand years formerly assigned as the age of created matter was too small, the reaction of opinion claimed for it an antiquity which workers in other branches of physics feel it impossible to concede; and at the present moment there is among scientific men a revolt against the extreme views of the geologists. The latter affirmed with truth that creation in six solar days was demonstrably untrue, not because God could not create the world at a stroke, but because the world bears ample evidence that he did not so exercise his power. It was inconsistent alike with reasoning from probability or the investigation of facts. In all the operations of Nature as they unfolded themselves before our eyes God worked by law—by the process of slow development—by means beautifully simple, and involving no violence and no haste, yet irresistible. There was abundant evidence that these causes had been at work for thousands—perhaps millions—of years before the date of the supposed miracle. Beginning from the present age, the time was calculated that each development would require, till the united ages of all amounted to the enormous sum of three hundred millions of years.

Modern English geology holds that all geological changes have been effected by agents now in operation, and that those agents have been working silently at the same rate in all past time; that the great changes of the earth's crust were produced, not by great convulsions and cataclysms of Nature, but by the ordinary agencies of rain, snow, frost, ice, and chemical action. It teaches that the rocky face of our globe has been carved into hill and dale, and ultimately worn down to the sea-level, not only once or twice, but many times over during past ages; that the principal strata of the rocks—hundreds, and even thousands, of feet thick—have been formed on ocean-floor-beds by the slow decay of marine creatures and matter held in solution by the waves; that every part of the earth has been many times submerged, and has again been lifted into the air. This slow rising and sinking of the ground is an axiom of the geological creed. We are told that it is now going on, and that there are large areas of subsidence and of elevation on the surface of the globe. But when we consider the slow rate at which that oscillation is now proceeding, and argue back from the known to the unknown, we are landed in conclusions as to the length of time required for geological changes which the opponents of the theory declare to be absolutely inadmissible.

Sir William Thomson, Prof. Tait, and Mr. Croll, argue the question as one of geological dynamics. They find reason, in recent discoveries of science, to assert that the sun and the earth, from their physical condition, cannot possibly have existed for the enormous length of time supposed. Playfair, the founder of what is called the Uniformitarian school of geology, declares, on the other hand, that in the existing order of things there is no evidence either of a beginning or of an end. "In the planetary motions," he says, "where geometry has carried the eye so far both into the future and the past, we discover no mark either of the commencement or the termination of the present order. The author of Nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction." This was a bold assertion: it was adopted with very little limitation by Sir Charles Lyell and the later geologists—his disciples and contemporaries. Indeed, if they admitted any limitations at all, they placed the origin of the world so many hundreds of millions of years ago that the figures convey no practical idea to the mind, and amount in effect almost to what a distinguished geologist calls "eternity *a parte ante*."

The principal grounds upon which scientific opinion has recently declared itself in favor of limited periods for the duration of the solar system are based, first, on the belief that the earth is cooling—if not rapidly—at such a rate as to make it impossible that it should have existed for very many millions of years; secondly, because there is reason to believe that the earth is not now rotating on her axis with the same rapidity as in former ages, and that, as her shape would have been different if, at the time she was in a molten state, she had been rotating more rapidly than now, she has not been rotating so long as has been supposed; thirdly, because the sun is parting with caloric at such a rate as to make it certain that he could not have continued to radiate heat at the same rate for more than a few millions of years; and lastly, because the changes in the earth's crust, stupendous and varied as they are, could have been, and probably were, accomplished in the course of much shorter periods than popular geology has hitherto considered possible.

It will, of course, be understood that any inquiry as to the date of creation must necessarily have relation only to the solar system—the sun, that is, and the planets which accompany the earth in its orbit round the central luminary.

The investigation is of necessity thus narrowed, because we have not, and cannot expect to have, any definite information as to the age of the rest of the visible universe. The stars are forever beyond our ken. If the spectroscope can bring intelligence of their component elements, it is as much as we can hope to attain; for their immeasurable distance effectually removes them from investigation. No action of gravity emanating from those distant luminaries affects the internal economy of the solar system. In the vast eternity of space the sun and his attendant satellites are altogether alone.

It is difficult to gaze upon the thousands of stars that brighten the night with their radiance, and yet realize our entire isolation. The solar system, with the radius of its orbit stretching from the sun to farthest Neptune, is but a point in a vast solitude. No star is nearer to us than 200 millions of millions of miles.

It is difficult, in dealing with such enormous numbers, to retain a definite impression on the mind. Our powers of conception are fitted rather to the wants of common life than to a complete survey of the universe.

Perhaps an intelligent may be substituted for a merely formal assent to these numbers, if they are considered on a greatly-diminished scale. Consider the figures on the scale of one mile to 100,000,000. On that scale the sun's distance from the earth will be represented by nearly one mile. Let the sun be represented by a globe on the top of St. Paul's Cathedral, and the earth by a little ball on the top of the clock-tower of the Houses of Parliament. The interior planets would revolve round St. Paul's as a centre; Mercury, at the distance of St. Clement's Church in the Strand; Venus, at the distance of St. Martin's Church, Trafalgar Square; Mars would be at Lambeth Bridge; Jupiter, at Walham Green; Saturn, in the middle of Richmond Park; Uranus, a little nearer the centre than Slough; Neptune, a couple of miles short of Reading. The outermost planet of the solar system, then, would on this scale revolve in an orbit comprising London and its neighborhood as far as Stevenage on the north, Chelmsford and Rochester on the east, and Horsham on the south.

On that same scale the nearest fixed star would be nearly as far away as the moon is in the actual heavens.[1]

This inconceivable remoteness shows that the sun and his satellites lie apart in space. They form one whole, interdependent on each other, but completely removed, as regards their internal economy, from the influence of any attraction outside.

There are reasons for concluding that the system, thus organized and isolated, was brought into existence by one continuous act of creative energy, and that, however long the period over which the process may have been spread, the whole solar system forms part of one creation; and though it has been sometimes thought that the earth was made by itself, and that the sun was introduced from outside space, or created where he is at a different time, the evidence is strong against such a supposition.

In the first place, the orbits of all the planets are nearly in one plane, and describe very nearly concentric circles. If, when they received the original impulse which sent them revolving round the sun, any of them had been started with a little more original velocity, such planets would revolve in orbits more elongated. If, therefore, they had been the result of several distinct acts of creation, instead of being parts of one and the same act of creation, their orbits would probably have been so many ovals, narrow and wide in all degrees, and intersecting and interfering with each other in all directions. Yet if this want of harmony had existed, even to a small degree, it would have been sufficient to destroy the existing species of living creatures, and cause to disappear all security for the stability of the solar system. If the earth's orbit were much more eccentric than it is, all living creatures would die, for the extremes

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[1] On the scale of 1 mile to 100,000,000 miles:

| | Miles. | | Miles. |
|---|---|---|---|
| Mercury would be distant from the sun | 0.35 | Saturn | 8.71 |
| Venus | 0.66 | Uranus | 17.52 |
| The earth | 0.91 | Neptune | 27.43 |
| Mars | 1.39 | And α Centauri, the nearest fixed star | 206,560.00 |
| Jupiter | 4.75 | | |

of heat and cold at different periods of the year would be fatal to life. If the orbit of Jupiter were as eccentric as that of Mercury, the attraction of the larger planet would cause the smaller to change their approximately circular orbits into very long ellipses; such would be the disturbance that they would fall into the sun or fly off into remote space. The moon would approach nearer and nearer to the earth with every revolution; the year would change its character; violent heat would succeed to violent cold; the planets would come nearer and nearer; we should see them portentous in size and aspect, glaring and disappearing at uncertain intervals; tides, like deluges, would sweep over whole continents; and, finally, the fall of the moon or one of the planets to the earth would result in the absolute annihilation of both of them.

Another reason for supposing that the solar system is the result of one separate act of creation is, that all parts of it are subject to one uniform law—that of gravitation. By that law every particle of matter attracts every other particle with a force directly proportionate to its mass. This force varies as the inverse square of the distance: that is, if the attractive force of a given mass at one mile were called 1, at two miles it would be $2 \times 2 = 4$, or $\frac{1}{4}$ of 1, and so on. This law of the inverse square, as it is called, is but the mathematical expression of a property which has been imposed upon matter by the Creator. It is no inherent quality, so far as we know. It is quite conceivable that the central law might have been different from what it is. There is no reason why the mathematical fact should be what it is except the will of the Being who imposed the law. Any other proportion could equally well be expressed mathematically, and its results calculated. As an instance of what would occur if any other proportion than the inverse square were substituted as the attractive force of gravity, suppose, at distances 1, 2, 3, the attractive force had varied as 1, 2, 3, instead of the squares of those numbers. Under such a law any number of planets might revolve in the most regular and orderly manner. But under this law the weight of bodies at the earth's surface would cease to exist; nothing would fall or weigh downward. The greater action of the distant sun and planets would exactly neutralize the attractive force of the earth. A ball thrown from the hand, however gently, would immediately become a satellite of the earth, and would for the future accompany its course, revolving about it in the space of one year. All terrestrial things would float about with no principle of coherence or stability—they would obey the general law of the system, but would acknowledge no particular relation to the earth. It is obvious that such a change would be subversive of the entire structure and economy of the world. From these and similar considerations, it follows that, although other laws are conceivable under which a solar system might exist, the solar system, such as we know it, could only exist under the actual laws which have been imposed upon its motions. And this seems entirely to exclude the idea that the various bodies of the system could have been created at different times or brought together from different parts of infinite space. We may then safely conclude that the solar system is absolutely isolated in space, and is collectively the result of one act of creation. To the solar system, therefore, our inquiry is exclusively confined.

Although the received chronology of the world has for ages rested upon the supposed authority of the Bible, the sacred text really says nothing at all upon the subject. But, though the assertions which were so long made upon its supposed authority are not really contained in the Pentateuch, it is curious to observe how exactly the words of Moses appear to fit the most recent discoveries of science. No one has supposed that we were intended to learn science from the Bible; it is, therefore, an unexpected advantage to find that its short but pregnant sentences directly support the interpretation put by modern research upon the hieroglyphics of Nature. Moses teaches, just as modern science teaches, that the starry heavens existed far back in past duration, before the creation of the earth. He describes in majestic words the "emptiness" of chaos, and the condition of affairs from which light arose. He describes the formation of the sun, and its gradual condensation into a "light-holder" to give light upon the earth, in terms that almost seem to anticipate Herschel and Laplace. Far from assigning any date to the Creation, he is content to refer it to "former duration." No date is either mentioned or implied.

The so-called chronology was derived from two lists, one extending from Adam to Noah, the other from Noah to Abraham. These lists purport to give the direct line of descent from father to son, and the age of each individual member of the genealogy at the time when the next in succession was born. As Adam was supposed to have been created six days after the commencement of the Creation, it was simple work to add up the sum and fix the age of the world. As long as the progress of physical science showed no necessity for supposing a lengthened period to elapse between the creation of the world and the creation of man, it was taken for granted, almost without discussion, that when God had created the heavens and the earth in the beginning, he at once set about the work of arranging them for the use of man; that he distributed this work over six ordinary days, and at the close of the sixth day introduced our first parent on the scene.

Nowadays, all divines, English and foreign, agree that the word employed by Moses, and translated in our Bible by "the beginning," expresses duration or time previous to creation. *Reshith*, the Hebrew word for beginning, is in the original used without the definite article. The article was expressly omitted in order to exclude the application of the word to the order of creation, and to make it signify previous duration or previous eternity. The words of Moses, then, "In former duration God created the heavens and the earth," may mean millions of years just as easily as one. A few verses later, describing the second day of creation, Moses declares that God made the firmament and called it heaven. It is plain from this that the heavens of the first day's creation are different from the heavens of the second day; the difference of time proves a difference of subject. The heavens of the first verse were made in former duration, before the moving of the Spirit, before the creation of light; the heavens of the second day were made after the earth and after light.

Another statement made by Moses is an extraordinary anticipation of the most recent cosmological doctrines. "The earth was desolation and emptiness and darkness upon the face of the raging deep, and the Spirit of God brooding upon the face of the waters." It is now hardly doubtful that the earth was a molten sphere, over which hung, in a dense vapor, all the water which now lies upon its surface. As the crust cooled, the aqueous vapor that surrounded it became condensed into water and rested on the surface of the land. The conflicts between the waters and the fiery heat, as the crust of the earth was broken, fell in, or was upheaved, are well described by the words of Moses, "The earth was desolation and emptiness." It is curious that the great facts of the submersion of the earth and its condition of emptiness should have been thus exactly described by Moses.

We are then told that God said, "Let there be light, and there was light." Celsus, Voltaire, and a writer in "Essays and Reviews," have found it strange that there should have been light before the creation of the sun; but, according to the theory of cosmogony now almost universally received, the earth did in fact exist before the condensation of the sun. Light there would be, from the gradually-condensing mass of nebulous and incandescent matter which occupied the whole space now circumscribed by the orbit of the earth. If Moses had wished to describe the modern doctrine concerning light, he could not have done so more happily. The sun is not called "ór," light, but Maór, a place of light, just what modern science has discovered it to be. If light be not matter, but vibrations of luminiferous ether, no words could more precisely explain what must have occurred when God set in motion the undulations which produced light, and said, "Let light be." The account given of the creation of the sun very closely anticipated modern science: "Let there be light-holders in the firmament of heaven, and let them be for light-holders in the firmament of heaven to give light upon the earth . . . and the stars." When the sun began to give his light, then, for the first time, the earth's fellow-planets, the stars, began to reflect his brilliance, and became luminaries also.

"Vestiges of Creation" was one of the first books which fairly awakened public interest in the debatable land which lies between that which is certainly known to science and that which must always defy inquiry. Before the appearance of that remarkable book, the theory that the sun and its attendant planets were produced by the condensation of a vast nebula was but little known to the unscientific world. The idea was originally entertained by Sir William Herschel, and affords one of the greatest proofs of his commanding genius. It was afterward elaborated by Laplace; but that great astronomer was himself distrustful of it, and, while he expounded the mechanical laws by which the proposed explanation could be supported, he was careful to speak of it only as an hypothesis. As time goes on, it seems probable that the saying of Arago will be accepted, and that the views of Laplace will be universally acknowledged to be "those only which, by their grandeur, their coherence, and their methematical character, can be truly considered to form a physical cosmogony."

But, though Laplace is thus credited by Arago with the origination of this grand conception, he was not its author. Sir William Herschel gave the earliest sketch of the theory. His views were expressed with so much precision, that one cannot help feeling a little jealousy for the prior right of discovery of the English astronomer. Herschel so plainly preceded Laplace, that it seems hard that Laplace should have the credit of it. Herschel began to search after nebulæ in 1779, and soon formed a catalogue comprising an enormous number of them. By degrees it dawned upon his mind that the differences he observed in them were systematic, and at length occurred the magnificent intuition that the nebulæ are stars in process of formation.

They lie in enormous numbers in every part of the heavens, and apparently in every stage of progressive development. The slow growth of worlds, extending over ages of time, cannot, of course, be watched by any single observer. No more can a single tree among the trees of a forest be so observed. But a forest contains specimens of saplings, young trees, trees of vigorous growth, and trees in decay. In like manner the heavens contain specimens of worlds in the making, from the chaotic mass of vapory matter which forms the first stage of cosmical existence to the perfect, self-luminous star. Herschel arranged them in classes showing this gradual development, and he declares that each class is so nearly allied to the next, that they do not differ so much as would the annual description of a human figure, if it were given from the birth of a child till he comes to be a man in his prime. His catalogue arranges the objects he has actually observed somewhat in the following fashion: first, patches of extensive diffused nebulosity; "milky nebulosity," with condensation; round nebulæ; nebulæ with a nucleus; and so on till he reaches stellar nebulæ, nearly approaching the appearance of stars.

The evidence grows irresistible as we read, that in these wonderful objects we are gazing at works in process of formation as they lie plastic under the creative hand of the Almighty. Nor is it possible to withhold the inference—thus probably was the world we live in, and the solar system of which we form a part, evolved out of chaos.

The labors of Laplace commenced where Herschel ended. Herschel described what he saw. Laplace showed by mathematics how the known laws of gravitation could form, and probably did form, from such partially-condensed mass of matter an entire planetary system.

It is supposed that a film of vaporous matter filled up the space which is now bounded by the orbit of the outermost planet of our system. To the eye of an observer, if such there were, in a distant star such a vapor would appear like one of the numerous nebulæ which are everywhere visible in the heavens.

Laplace supposed that this nebula, extending beyond what is now the orbit of Neptune, possessed a rotatory motion round its centre of gravity, and that the parts of it which were situated at the limits where the centrifugal force exactly counterbalanced the attractive force of the central nucleus were abandoned by the central mass. Thus, as the nucleus became more and more dense under the action of gravity, were formed a succession of rings concentric with and revolving round the centre of gravity. Each ring would break up into masses which would be endued with motions of rotation, and would in consequence assume a spheroidal form. These masses formed the various planets, which, in their turn condensing, cast off in some instances their outlying rings, as the central mass had done, and thus formed the moons or satellites which accompany the planets. As each planet was in turn cast off, the central mass contracted itself within the orbit of that last formed, till, after casting off Mercury, it gathered with immense energy round its own centre and formed the sun.

Laplace's mechanical explanation does not rest only on theory. It has been experimentally shown that matter under certain conditions would exhibit phenomena similar in many important particulars to those which Laplace was led by mathematical considerations to suppose. Prof. Plateau, several years ago, tried the experiment of pouring olive-oil into alcohol and water, mixed in such proportions as exactly to equal the density of the oil. The oil thus became a liquid mass relieved from the operation of gravity, and free to take any exterior form which might be imposed by such forces as might be brought to bear upon it. The oil instantly took the form of a globe by virtue of molecular attraction. Prof. Plateau then introduced a wire into the globe of oil in such a manner as to form for it a vertical axis. The wire had on it a little disk coincident with the centre of the globular mass, and by turning the axis the oil was made to revolve. The sphere soon flattened at the poles and bulged out at the equator, thus producing on a small scale an effect which is admitted to have taken place in the planets. The experiment has since been several times repeated. When the rotation becomes very rapid, the figure becomes more oblately spheroidal, then hollows out above and below round the axis of rotation, stretches out horizontally until finally the outside layer of oil abandons the mass and becomes transformed into a perfectly regular ring. After a little while the ring of oil, losing its own motion, gathers itself once more into a sphere. As often as the experiment is repeated the ring thrown off immediately takes the globular form. These are seen to assume at the instant of their formation a movement of rotation upon themselves, which takes place in the same direction as that of the ring. Moreover, as the ring at the instant of its rupture had still a remainder of velocity, the spheres to which it has given birth tend to fly off at a tangent; but, as on the other side, the disk, turning in the alcoholic liquor, has impressed on the liquor a movement of rotation, the spheres are carried along and revolve for some time round the disk. Those which revolve at the same time upon themselves "present the curious spectacle of planets revolving at the same time on themselves and in their orbit." Another curious result is almost always exhibited in this experiment. Besides three or four large spheres into which the ring resolves itself, there are almost always two or three very small ones which may thus be compared to satellites. The experiment presents, therefore, an image in miniature of the formation of the planets, according to the hypothesis of Laplace, by the rupture of the cosmical rings attributable to the condensation of the solar atmosphere.

Modern discoveries carry the matter on much further. Recent investigations into the doctrine of the conservation of energy have shown the generation of cosmical heat. The amount of force comprised in the universe, like the amount of matter contained in it, is a fixed quantity, and to it nothing can either be added or taken away. It is, therefore, constantly undergoing change from one form to another. If it ceases in one form it is not destroyed, it is converted. The blow of a hammer on an anvil sets a certain amount of energy in motion. The anvil stops the blow, but the force changes into heat. Hammer a nail, and it will burn your fingers. Apply a brake to a wheel, and you will stop the motion, but the force will be changed into heat, which will burn you if you touch the brake. Measure the hammered nail, and you find that it has expanded by the vibration of its particles; heat it still more, and the particles will overcome the attraction of cohesion and revolve about each other, that is, they will become molten; heat them still more, and they will assume the vaporous or gaseous form. Now, seeing that motion was convertible into heat, and heat into motion, it became an object of inquiry what was the exact relation between the two. Dr. Mayer, in Germany, and Dr. Joule, in England, set themselves to the solution of this problem. By various experiments it was demonstrated that, every form of motion being convertible into heat, the amount of heat generated by a given motion may be calculated. If the particles of a vast vaporous mass were brought into collision from the effect of their mutual attraction, intense heat would ensue. The amount of caloric generated by the arrest of the converging motion of a nebula like the solar system would be sufficient to fuse the whole into one mass and store up a reserve of solar heat for millions of years.

Such, then, is the most probable conjecture respecting the origin of our system. We now turn to consider the grounds on which attempts have been made to fix the probable date of its creation. It will be convenient to examine the views of modern geologists on the subject, and the objections, based on recent results of physical science, which natural philosophers have adduced against their speculations.

The great representative, in late years, of British geology, is the late Sir Charles Lyell. But a few months before his death he published the new edition of his "Principles of Geology," the title of which we have placed at the head of this paper. While he lived he bestowed upon the correction of his works unwearied labor. Edition after edition was called for, and in each whole passages—sometimes whole chapters—were remodeled. A quotation from one of the earlier editions may not improbably be searched for in vain in those which subsequently left his hands; and there are not wanting instances in which an opinion, contested by competent adversaries, was quietly dropped without any formal parade. His judgment was always open to appeal, and his clear and manly intellect acknowledged no finality in matters of opinion; therefore, on matters which we know to have been brought before him, with their accompanying evidence, we may consider ourselves as possessing his final verdict. It would not be fair when quoting, as we must do, comments unfavorable to some of the conclusions at which Sir Charles Lyell arrived, to refrain from acknowledging the care with which his opinions were formed, and the candor with which they were surrendered if ever his better judgment considered them untenable. For instance, as head of the Uniformitarian school, he was exceedingly anxious that the evidence for his favorite doctrine should be duly and impartially weighed. With this view he advocated, in his "Principles of Geology,"[1] "an earnest and patient endeavor to reconcile the indications of former change with the evidences of gradual mutations now in progress."

Upon this remark Dr. Whewell[2] fell with merciless severity: "We know nothing," says he, "of causes; we only know effects. Why then should we make a merit of cramping our speculations by such assumptions? Whether the causes of change do act uniformly;

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[1] Lyell, b. iv., p. 328, fourth edition.

[2] "History of the Inductive Sciences," b. viii., sec. 2, edition of 1857.

whether they oscillate only within narrow limits; whether their intensity in former times was nearly the same as it is now: these are precisely the questions which we wish science to answer us impartially and truly. Where, then, is the wisdom of 'an earnest and patient endeavor' to secure an affirmative reply?"

This was rough handling of a pet theory, or, rather, of an argument in favor of a pet theory; but that Sir Charles Lyell felt its force is shown by the fact that no trace of the appeal attacked by Whewell appears in such later editions of the "Principles" as we have consulted.

As another instance of the same spirit, the following remark was made by Dr. Hooker, the President of the Royal Society, when addressing the British Association at Norwich. He was speaking of the progress made in public estimation by the theories of Mr. Darwin. "Sir Charles Lyell," he says, "having devoted whole chapters of the first edition of his 'Principles' to establishing the doctrine of special creations, abandons it in the tenth edition. I know no brighter example of heroism, of its kind, than this, of an author thus abandoning late in life a theory which he had for forty years regarded as one of the foundation-stones of a work that had given him the highest position attainable among contemporary scientific writers."

Among eminent persons holding the geological opinions to which the name of Catastrophism has been given, the name of the late Master of Trinity must occupy a foremost place. The words in which he avows his opinion are remarkable, not only for their exquisite beauty, but because they have a peculiar significance as almost the last utterance of a great man. The passage which follows[1] occurs in the third of a series of sermons preached in the University Church at Cambridge, in 1827. But it is curious to learn, from his "Memoirs," published this year, that he again used the same words in his college chapel just before his death:

> "Let us not deceive ourselves. Indefinite duration and gradual decay are not the destiny of this universe. It will not find its termination only in the imperceptible crumbling of its materials, or the clogging of its wheels. It steals not calmly and slowly to its end. No ages of long and deepening twilight shall gradually bring the last setting of the sun—no mountains sinking under the decrepitude of years, or weary rivers ceasing to rejoice in their courses, shall prepare men for the abolition of this earth. No placid euthanasia shall silently lead on the dissolution of the natural world. But the trumpet shall sound—the struggle shall come—this goodly frame of things shall be rent and crushed by the arm of its omnipotent Maker. It shall expire in the throes and agonies of some fierce convulsion; and the same hand which plucked the elements from the dark and troubled slumbers of chaos shall cast them into their tomb, pushing them aside that they may no longer stand between his face and the creatures whom he shall come to judge."

Holding these opinions, and believing as Prof. Whewell did that

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[1] "Sermons in the University Church at Cambridge, 18th February, 1827."

the upheavals and subsidence of strata which characterize the earth's crust were produced suddenly, and by violent agencies, the school to which he belonged were little likely to attempt to fix a date for the creation of the world. To their minds the facts of geology gave no evidence as to time. It is, therefore, to Sir Charles Lyell and his followers that we must turn for an estimate of duration drawn from the "testimony of the rocks."

It is impossible to deny that periods of very vast duration must have elapsed while the changes took place of which we see the traces. If, for instance, we search below the sand on English shores, we find, perhaps, a bed of earth with shells and bones; under that, a bed of peat; under that, one of blue silt; under that, a buried forest, with the trees upright and rooted; under that, another layer of blue silt, full of roots and vegetable fibre; perhaps, under that, again, another old land-surface, with trees again growing in it; and, under all, the main bottom clay of the district. In any place where bowlder clay crops out at the surface—in Cheshire or Lancashire, along Leith shore near Edinburgh, or along the coast of Scarborough—it will be found stuffed full of bits of different kinds of stone, the great majority of which have nothing to do with the rock on which the clay happens to lie, but have come from places many miles away. On examining the pebbles, they will prove to be rounded, scratched, and grooved, in such fashion as to show that at some period they have been subjected to a grinding force of immense violence. Among the pebbles in the clay, and on plains far away from mountains, are found great rocks of many tons in weight. They were carried on the backs of icebergs, which, at some time, covered the now temperate regions of the earth, and were dropped by the melting ice either in the shape of pebbles, as moraines of ancient glaciers, or as bowlders stranded when the icebergs melted in the lowlands.

Such evidence points to vast periods of more than arctic winter, which must have endured for many thousand years. But in close juxtaposition with these glacial shells and pebbles lie remains which tell of tropical climates that alternated with the dreary ages of ice. Fossil plants and the remains of animals prove that all Northern Europe was once warmer than it is now; that England bore the flora and fauna of the torrid zones. Underneath London there lies four or five hundred feet of clay. It is not ice clay; it belongs to a later geological formation, and was, in fact, the delta of a great tropical river. The shells in this clay are tropical—nautili, cones, fruits, and seeds of nipa palms, now found only at Indian river-mouths; anona-seeds, gourd-seeds, acacia fruits; the bones, too, of crocodiles and turtles; of large mammals allied to the Indian tapir, and the water-hog of the Cape. All this shows that there was once, where London stands, a tropical climate, and a tropic river running into the sea. We find in it the remains of animals which existed before the Ice age.

The mammoth, or woolly elephant, the woolly rhinoceros, the cave-lion, the cave-bear, the reindeer, and the musk-ox, inhabited Britain till the ice drove them south. When the climate became tolerable again, the mammoth and rhinoceros, the bison and the lion, reoccupied our lowlands; and the hippopotamus from Africa and Spain wandered over the plains where now the English Channel flows, and pastured side by side with animals which have long since retreated to Norway and Canada.

When the ages necessary for all these changes is allowed for, we have not, even yet, got beyond the latest period into which the history of the globe has been divided. Under the tertiary deposits lies the chalk, a thousand feet in thickness, which is composed of the shells of minute animals, which must have been deposited age after age at the bottom of a deep and still ocean, far out of reach of winds, tides, or currents. Recent dredgings in ocean-depths have proved beyond a doubt that the greater part of the Atlantic Sea floor is now being covered by a similar deposit. It must have taken ages to form, and, if the geologists are right in their estimate of the slow rate of upheaval, many more ages to become elevated above the ocean-bed where it lay. Not only once, but many times, the chalk was alternately above and beneath the waves. It is separated by comparatively thin and partial deposits of sand and clays, which show that it has been at many different points in succession a sea-shore cliff. The chalk is not flat, as it must have been at the sea-bottom; it is eaten out into holes by the erosion of the sea-waves, and upon it lie flints, beds of shore-shingle, beds of oysters lying as they grew, water-shells standing as they lived, and the remains of trees. Yet, again, there lie upon the chalk sands, such as those of Aldershot and Farnham, containing in their lower strata remains of tropical life, which disappeared as the climate became gradually colder and colder, and the age of ice once more set in. Everywhere about the Ascot Moors the sands have been ploughed by the shore-ice in winter, as they lay awash in the shallow sea, and over them is spread in many places a thin sheet of ice-borne gravel. All this happened between the date of the bowlder clay and that of the New Red Sandstone on which it rests.

We need not follow the geologist through the lower systems which overlie the metamorphic rock. The Oolite contains remains of plants and animals now extinct, the most remarkable being huge reptiles; the Triassic has fossils like the Oolite; and the Permian has remains like those in the coal on which it rests. Then follow the coal-measures, the fossil remnants of tropical vegetation; the Old Red Sandstone, with fossils principally of fishes and shells; the Silurian, in which are found the earliest forms of life; and, lastly, the hard and crystalline rocks, devoid of fossils, which are supposed to be the earliest constituent mass of our planet.

Sir Charles Lyell and his followers allege that the rate at which species of animals change is tolerably uniform. The fossils of one age differ but little from those of ages immediately preceding and following it. We must go back, he says, to a period when the marine shells differ as a whole from those now existing to form one complete period. Counting back in stages measured by changes of fossils, we have four such stages in the tertiary formations above the chalk.

Lyell saw reason to believe, on evidence which we shall presently examine, that the age of ice commenced about a million of years ago. The place of this age of ice among the series of fossil-changes is easily marked, and so he concludes that each of his four periods above the chalk "would lay claim to twenty millions of years." We must allow Sir Charles to work up to his stupendous conclusion in his own words:

> "The antecedent Cretaceous, Jurassic, and Triassic formations would yield us three more epochs of equal importance to the three Tertiary periods before enumerated, and a fourth may be reckoned by including the Permian epoch with the gap which separates it from the Trias. In these eight periods we may add, continuing our retrospective survey, four more, namely, the Carboniferous, Devonian, Silurian, and Cambrian; so that we should have twelve in all, without reckoning the antecedent Laurentian formations which are older than the Cambrian. . . . If each, therefore, of the twelve periods represents twenty millions of years on the principles above explained, we should have a total of two hundred and forty millions for the entire series of years which have elapsed since the beginning of the Cambrian period."

Eighty millions since the lower tertiary formation, one hundred and sixty millions since the formation of the coal-measures, and two hundred and forty millions since the beginning of the Cambrian period! And beyond that inconceivable antiquity lie the whole range of the primary rocks which contain no fossils.

Mr Darwin[1] assigns to the world even a greater age. "In all probability," he says, "a far longer period than three hundred millions of years has elapsed since the latter part of the secondary period." Other geologists exceed even this estimate. Mr. Jukes, for instance, after referring to this passage, in which Mr. Darwin has given an estimate of the length of time necessary for wearing down the space between the North and South Downs, declares it is just as likely that the time which actually elapsed since the first commencement of the erosion, till it was nearly as complete as it now is, was really a hundred times greater than his estimate, "or *thirty thousand millions of years!*"

To any one but a professed geologist, it would almost seem as if these ideas of geological periods had been framed on the principle which guided Mr. Montague Tigg in fixing the capital of the Anglo-Bengalee Disinterested Loan and Life-Insurance Company. "What," asked the secretary, "will be the paid-up capital according to the

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[1] "Origin of Species," edition of 1859, p. 287.

next prospectus?" "A figure of two," says Mr. Tigg, "and as many naughts after it as the printer can get into the same line."

It is hard for imagination to compass the meaning of a million, and, when that number is multiplied by hundreds, the effort is altogether beyond us. But we need not dwell on this consideration; we turn at once to the practical comments made by physical science on these and such-like opinions. The first is founded on the secular cooling of the earth.

If a red-hot ball be taken from a furnace, it begins at once to part with heat at a certain definite rate. As it becomes colder it cools more and more slowly. From the known laws of heat it is quite possible roughly to approximate to the period during which the earth has been habitable for animals and plants such as we now find upon it. Whenever a body is hotter at one part than at another, the tendency of heat is to flow from the hotter body to the colder. As the earth's crust is warmer as we go farther down, there must be a steady increase of heat from the surface to the centre, and the earth is even now losing heat at a perfectly measurable rate; therefore it is possible to calculate what was the distribution of heat a hundred thousand or a thousand thousand years ago, supposing the present natural laws to have been then in existence. According to these data, about ten millions of years ago the surface of the earth had just consolidated, or was just about to consolidate; and in the course of comparatively few thousand years after that time the surface had become so moderately warm as to be fitted for the existence of life such as we know it. If we attempt to trace the state of affairs back for a hundred millions, instead of ten millions of years, we should find that the earth (if it then existed at all) must have been liquid, and at a high white heat, so as to be utterly incompatible with the existence of life of any kind with which we are acquainted.[1]

The next argument, namely, that founded on the earth's retardation by the tidal wave, is more recondite, and the theory that there is such a retardation at all is quite of recent date. Theoretical reasons connected with mechanics caused it to be adopted, and its establishment depends on the most refined astronomical investigation.

It is one of the peculiarities of time-measurement that, from the nature of things, no two periods of time can be compared directly one with another. The standards by which we measure time are less and less precise as we recede farther into the past. To-day we have as the standard unit of duration the interval between two successive transits of a star over the cross-wires of a fixed observatory-telescope. This measure has been considered until lately as absolutely fixed and invariable. And so it is for all practical purposes; the sidereal time of any heavenly body passing the meridian on a given day in 1880

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[1] "The 'Doctrine of Uniformity' in Geology briefly refuted." "Proceedings of the Royal Society, Edinburgh, December, 1865."

may be ascertained from the "Nautical Almanac" to-day, and it will be found true within one-hundredth of a second. But that throws no light on the question, What is the absolute length of an hour or a second? They are both definite fractions of a day; and a day is a revolution of the earth on its axis; no artificial measurement of such an interval can prove whether the interval itself remains from age to age unchanged. To quote Humboldt as a sure guide to the received opinions of scientific men thirty years ago,[1] "The comparison of the secular inequalities in the moon's motion, with eclipses observed by Hipparchus, or during an interval of two thousand years, shows conclusively the length of the day has certainly not been diminished by one-hundredth part of a second."

The assertion is derived from Laplace, and even now is mentioned as an unquestioned fact in the most recent astronomical text-books. Halley, it is true, in 1695, discovered that the average velocity with which the moon revolves round the earth had apparently been increasing from year to year, and this acceleration remained unexplained during more than a century. Halley compared the records of the most ancient lunar eclipses of the Chaldean astronomers with those of modern times. He likewise compared both sets of observations with those of the Arabian astronomers of the eighth and ninth centuries. The result was an unexplained discrepancy, which set all theory at defiance for a century or more. It appeared that the moon's mean motion increases at the rate of eleven seconds in a century; and that quantity, small in itself, becomes considerable by accumulation during a succession of ages. In 2,500 years the moon is before her calculated place by 1½°—enough to make a very material difference in place of visibility of a solar eclipse. Laplace at last, as Sir John Herschel says, stepped in to rescue physical astronomy from its reproach, by pointing out the real cause of the phenomenon. Laplace accounted for the apparent acceleration by showing that the motion of the earth in her orbit was disturbed by the other planets, in a manner before insufficiently appreciated, and the explanation was accepted for many years as complete and satisfactory. The acceleration was calculated to the utmost point of precision attainable in mathematics by MM. Damoiseau and Plana. Using the formulæ of Laplace, and the numbers deduced from them, it was found that the circumstances and places of ancient eclipses, as recorded by historians, were brought into strict accordance with the times and circumstances as they ought to have been if the theory were true. Laplace's explanation rests upon the fact that for many thousands of years past the orbit of the earth has been tending more and more to a perfect circle—that is, the minor axis is increasing while the major axis remains unchanged. The result is, that the average distance of the moon from the sun is greater than it was in past ages. But in proportion as the moon

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[1] "Cosmos," i., 161.

is released from the sun's influence she revolves faster round the earth.

When it was seen how completely the difficulties in ancient observations were explained away by the calculations of Laplace, all doubt was considered to be at an end, and astronomers supposed that the whole truth was known. But, in 1853, it occurred to Prof. Adams to recalculate Laplace's investigations, and the result was the detection of a material error, which vitiated the whole series of observations. The results of Prof. Adams's calculations were submitted to the Royal Society[1] in a paper, the explanatory part of which is very short indeed, occupying but a couple of pages of the "Proceedings." The brief statement is followed by a corroborative sea of high mathematics, into which we have no intention of asking the reader to plunge. The result, roughly stated, was to halve the amount of acceleration calculated by Laplace, and thus to leave half of the acceleration of the moon necessary for his explanation of ancient eclipses to be found in some other way. Astronomers were now in a condition almost as bad as that from which they had been rescued by Laplace.

Adams communicated his final result to M. Delaunay, one of the great French mathematicians; and it seems to have been during the investigations which that astronomer undertook to verify the calculations of Adams that it occurred to him to inquire whether our measure of time itself remains unchanged? in other words, whether the earth itself may not be rotating more slowly, instead of the moon more quickly, than in by-gone ages? It is plain that the moon will appear to be moving more quickly round the earth, if the earth itself —which is furnishing the standard by which the moon's revolution is to be measured—is rotating more and more slowly from age to age.

Newton laid it down in his first law of motion that motion unresisted remains uniform forever; and he gave as an instance of constant motion, unaffected by any external causes, this very rotation of the earth about its axis. But M. Delaunay remembered that Kant had pointed out the resistance which the earth must incur from the tide-wave, and had even approximately calculated its amount. The tidal wave is lifted up toward the moon, and on the side of the earth opposite the moon; so that, as Prof. Tait puts it, the earth has always to revolve within a friction-brake. Adams adopted this theory of tidal friction; and, in conjunction with Prof. Tait and Sir William Thomson, assigned twenty-two seconds per century as the error by which the earth would, in the course of a century, get behind a thoroughly-perfect clock (if such a machine were possible).

It may be asked, If the earth's movement be diminishing gradually in rapidity, will it eventually stop altogether? No; if ever the earth shall so far yield to the action of the tidal wave as to rotate not more rapidly than the moon, she will present to the moon always the

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[1] June 16, 1853.

same part of her surface. Then the liquid protuberance directed toward the moon will no longer be a cause of delay, and the retardation will cease. This cessation of effect, owing to the cause having ceased, appears to have actually happened with regard to the moon herself. At some time the moon's crust, and, indeed, her whole substance, was in a molten state. Enormous tides must have been produced by the attraction of the earth in this viscous mass of molten rock, and the time of the moon's rotation must have been quickly compelled, by the friction, to become identical with the time of its revolution round the earth, and now, as is well known, the moon always presents to the earth the same side of her sphere.

It being thus established that there is retardation of the earth's motion, and the amount of retardation being calculated, it remains only to inquire how the fact affects the question of the world's age. We know that the flattening at the poles and bulging at the equator is the result of rotation; from the amount of retardation it can be calculated how fast the earth was rotating in by-gone ages. Two thousand millions of years ago she would, according to such calculation, have been revolving twice as fast as at present, and the amount of centrifugal force at the equator would have been four times as great as now. If the earth, subjected to such strong centrifugal force, had been liquid or even pasty, when it began to rotate, the equatorial protuberance would have been much greater than it is. It therefore follows that she was rotating at about the same rapidity as now, when she became solid, and as the rate of rotation is certainly diminishing, the epoch of solidification cannot be more than ten or twelve millions of years ago.

A third argument for restricted periods is founded on an examination of the question, How long can the sun be supposed to have kept the earth, by its radiation, in a state fit to support animal and vegetable life? Here, as might be expected, a wider range of opinion exists.

It will be conceded at once that the age of organic life upon the earth must, of necessity, be more recent than the age of the sun. The several theories as to the way in which the sun may have derived his heat may be put aside in favor of that of Helmholtz, viz., that the sun has been condensed from a nebulous mass, filling at least the entire space at present occupied by the whole solar system. The gravitation theory of Helmholtz is now generally admitted to be the only conceivable source of the sun's heat. The opinion that it can be obtained from combustion is not tenable for a moment. The amount of heat radiated is so enormous that, if the sun were a mass of burning coal, it would all be consumed bodily in 5,000 years![1] On the other hand, a pound of coal falling on the surface of the sun

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[1] To maintain the present rate of radiation it would require the combustion of 1,500 pounds of coal on every square foot of the sun's surface per hour.—Croll, 346.

from an infinite distance would produce 6,000 times more heat from concussion than it would generate by its combustion. An idea of the amount of energy exerted by one pound weight falling into the sun will be conveyed by stating that it would be sufficient to hurl the Warrior, with all its stores, guns, and ammunition, over the top of Ben Nevis![1] But, if we accept gravitation as the source of energy, we accept a cause, the value of which can be mathematically determined with very considerable accuracy.

The amount of heat given off by radiation in a year[2] is known; the total amount of work performed by gravitation in condensing a nebulous mass to an orb of the sun's present size is known. The result is, that the amount of heat thus produced by gravitation would suffice for about twenty millions and a quarter of years. This is on the assumption that the nebulous matter composing the sun was originally cold, and that heat was generated in it by the process of condensation only. It is, however, quite conceivable that the nebulous mass possessed a store of heat previous to condensation, and that the very reason why it existed in the gaseous condition was that its temperature was excessive. The particles composing it would have had a tendency, in virtue of gravitation, to approach one another if they had not been kept apart by the repulsive energy of heat; it is not, then, unreasonable to suppose that the attenuated and rarefied mass was vaporous by reason of heat, and began to condense only when its particles began to cool. By the known laws under which heated gases condense, the amount of heat originally possessed by the gas bears a definite and known proportion to the amount of heat generated by condensation; and, on the assumption that the analogy holds good in the case of the sun, which holds in the condensation of other heated gases, nearly fifty millions of years' heat must have been stored up in the mass as original temperature. This, added to the twenty and a quarter millions which resulted from gravitation, gives rather more than seventy millions of years' sun-heat.

As, however, this quantity gives the total amount of heat given out by the mass since it began to condense, the earth could not have had an independent existence till long after that time. The sun must have had time to condense from its outer limits as a nebula, to within

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[1] The velocity with which a body falling from an infinite distance would reach the sun would be equal to that which would be generated by a constant force equal to the weight of the body at the sun's surface operating through a space equal to the sun's radius. One pound would at the sun's surface weigh about twenty-eight pounds. Taking the sun's radius at 441,000 miles, the energy of a pound of matter falling into the sun from infinite space would equal that of a 28-pound weight descending upon the earth from an elevation of 441,000 miles, supposing the force of gravity to be as great at that elevation as it is at the earth's surface. It would amount to upward of 65,000,000,000 foot-pounds.

[2] The total amount radiated from the whole surface of the sun per annum is $8,340 \times 10^{30}$ foot-pounds.—Croll, 346.

the limit of the earth's orbit, before that separate existence could begin; for before then the earth must have formed part of the fiery mass of the sun. This calculation, like the others, falls short by nearly two hundred millions of years of the period estimated by Sir Charles Lyell for the commencement of life upon the earth.

But it would not be satisfactory to see a theory upset, if with the theory the means of accounting for observed facts were also destroyed. One great reason which weighs with geologists in assigning an almost incalculable age to the earth is, that among the fossils of the latest glacial epoch there are found the remains of tropical plants and animals, deposited in alternate strata with the remains of temperate climates, and this not once, but many times over. A hot climate prevailed at one time, and the earth became peopled with the flora and fauna appropriate to those conditions: after a lapse of many ages, the land subsided, and became the bed of the ocean; a vast period of upheaval then ensued, and dry land once more appeared: the climate gradually changed and ice set in: after ages more there was another slow subsidence, another equally slow upheaval, and another change of climate; and so on without end. Seeing the slow way in which the land sinks or is upheaved nowadays, it naturally appeared that no conceivable lapse of time could be enough to explain that which had obviously taken place.

Mr. Croll, however, has recently afforded an explanation at once beautiful, simple, and complete. About the facts to be accounted for there can be no doubt. The land has been many times under the sea, and the most violent changes of climate have succeeded one another. Mr. Croll's explanation is partly astronomical, and partly rests on geological dynamics. The heat of the sun is great in proportion to his distance from the earth. This distance is greater at one time of the year than another. The orbit of the earth is not quite circular, but its eccentricity varies slowly from century to century. It is just now very small, and the summer of the northern hemisphere happens when the earth is at its greatest distance from the sun. Both these circumstances tend to produce in Europe a moderate climate. But the longitude of the perihelion, as this state of things is called, is constantly changing, and the line joining the solstices moves round the orbit in about twenty-one thousand years. It follows that every ten thousand years, or thereabouts, the winter of the northern hemisphere will occur when the earth is at its farthest from the sun; and, if at that time the earth's orbit is very eccentric, the two causes combined will produce a very severe climate. Eleven thousand years hence the northern hemisphere will be nearest to the sun in summer, and farthest from him in winter. Now, if, when that state of things occurred, the eccentricity of the earth's orbit happened to be very great—if the earth in winter-time was at a part of her orbit several millions of miles farther from, and in summer-time was very much nearer, the sun than she is now, the climate of the northern hemisphere would be very different from what it is.

One such period of great eccentricity occurred about two million five hundred thousand years ago. Fifty thousand years later there was another. Again, eight hundred and fifty thousand years ago there was a third, and two hundred thousand years ago a fourth. Those periods were characterized by cold such as we have no conception of. More than arctic winter lingered far on into the spring, and unmelted ice of one year accumulated through the next, till from the pole to the south of Scotland the earth was covered with a vast ice-cap, probably several miles in thickness.

Now, in Europe and America, wherever in fact any records are left of the glacial epoch, it is remarked that a general subsidence of the land followed closely on the appearance of the ice. This fact led certain geologists to conclude that there was some physical connection between the two phenomena, and Mr. Jamieson suggested to the Geological Society that the crust of the earth might have yielded under the enormous weight of the ice. Mr. Croll, however, gives a different explanation; and the more it is understood the more it appears to gain ground with those capable of forming an opinion. He says that the surface of the ocean always adjusts itself in relation to the earth's centre of gravity, no matter what the form of the earth happens to be. If a large portion of the water of the ocean were formed into solid ice, and placed round the north pole, its weight would naturally change the centre of gravity of the earth. The centre would be changed a little to the north of its former position. The water of the ocean would then forsake its old centre, and adjust itself with reference to the new. The surface of the ocean will therefore rise toward the north pole, and fall toward the south. The land will not sink under the sea, but, what amounts to the same thing, the sea will rise upon the land. The extent of submergence will be in proportion to the weight of the ice.

It is easy to see that glaciation would not be contemporaneous on both hemispheres. One hemisphere would be covered with ice and snow, while the other would be enjoying a perpetual spring. A glacial epoch resulting from the eccentricity of the earth's orbit would extend over a period of a hundred thousand years. But, for the reason given above, the glaciation would be transferred from one hemisphere to another every ten thousand years. A glacial epoch extending over a hundred thousand years would therefore be broken up into several warm periods. The warm period in one hemisphere would coincide with the cold one in the other, and there would be elevation of the land during the warm period and subsidence during the cold.

This cause would be quite sufficient to effect the alternate upheaval and depression. During the successive ages that each pole alternately was subjected to glaciation, the winter ice, unmelted by the brief summer, would accumulate till a cap many thousand feet thick formed at the pole, and would ultimately spread far down into what is now the temperate zone. If such an ice-cap were only equal in density to 1,000 feet of earth, accumulated, say, on the north side of the globe, the centre of gravity would be shifted 500 feet to the north; and as the ocean would accommodate itself to the centre there would be a subsidence at the north pole equal to 500 feet. But this is not all, for at the time the ice-sheet was forming on the northern hemisphere, a sheet of equal size would be melting on the southern. This would double the effect, and produce a total submergence of 1,000 feet at the north pole and a total elevation of 1,000 feet at the south pole.

It is clear that all the upheavals and submergences of land which have so impressed geologists with the immensity of time required for their execution can thus be accounted for within periods, stupendous indeed if compared to historical time, or even to the duration of man on the earth, but still conceivable by human imagination. The nightmare of subsidence and emergence need no longer oppress the geologist. He has only to remark surface-changes and see how far forces now at work are capable of effecting them, and, if so, how long they would take. The discovery of Mr. Croll upsets the whole scale of geological time. Sir Charles Lyell was quite right in saying that the earth could not have subsided and emerged from the sea half a dozen times, in less than a million of years, if it sank or rose in the leisurely manner which has characterized it in recent times: consequently he could not accept as "the glacial epoch" the most recent period of great eccentricity. He was obliged to go back to the next, which happened nearly a million years ago. Sir Charles Lyell's standard of measurement is the date of the age of ice. If, therefore, the age of ice is assigned to a period 200,000 years ago instead of a million years ago, the standard of Sir Charles Lyell is diminished by four-fifths; and, adapting his conclusions to the altered premises, we should have forty-eight millions of years instead of two hundred and forty millions for the age of the fossiliferous rocks.

This change of standard would agree very well with the fact that there are evidences in the Eocene and Miocene periods of ice ages antecedent to the last. These might well be referred to the former periods of high eccentricity.

Enormous as are the periods which have undoubtedly passed since the creation of the world, it need not startle us to be told that every succession of events of which we have any evidence may well have occurred within a manageable number of millions of years. Could we stand, as Mr. Croll says, upon the edge of a gorge a mile and a half in depth, that had been cut out of the solid rock by a tiny stream scarcely visible at the bottom of this fearful abyss, and were we informed that the little streamlet was able in one year to wear off only one-tenth of an inch of its rocky bed, what would be our conception of the prodigious length of time that it must have taken to excavate the gorge? We should certainly feel startled when on making the necessary calculations we found that the stream had performed this enormous amount of work in something less than a million years.

The absolute settlement of the question must ever be above our powers. For a few centuries only we have the comparative daylight of historical times; thence backward lies the rapidly-gathering twilight of tradition; beyond that, geological periods the duration of which can be only vaguely guessed at, and beyond all these, far back in past eternity, the epoch when Time began. The old belief, which limited the existence of the earth to less than seven thousand years, gave way once for all, almost within living memory. All men are now agreed that the six days of creation were periods of indefinite extent. They are not solar days—for evening happened and morning happened three times over before the sun was created. Not being days measured by the sun, we know not how many thousands of years they may have endured. The reaction was sudden and complete. Geology jumped to the conclusion that the past history of the world was without any limits that human imagination could conceive. But in quite recent years, as we have tried to show, the calm light of science has proved that the practical eternity of matter is not more tenable than the arbitrary limitation by which thought was formerly confined.

> "I dare say," says Prof. Tait, "that many of you are acquainted with the speculations of Lyell and others, especially of Darwin, who tell us that even for a comparatively brief portion of recent geological history three hundred millions of years will not suffice! We say—so much the worse for geology as at present understood by its chief authorities, for . . . . physical considerations render it impossible that more than ten or fifteen millions of years can be granted."

Sir William Thomson is not so sweeping in his assertion: but then the nature of the problem before him did not require any such opinion at his hands. His argument aimed at disproving Playfair's assertion that neither the heavenly bodies nor the earth offered any evidence of a beginning, or any advance toward an end. If, therefore, Sir William Thomson was able to show that there was good evidence both of a beginning and an end, he was not concerned to speculate how long past time had existed, or when the end would come. His summing up is this:

> "We must admit *some* limit. . . . Dynamical theory of the sun's heat renders it almost impossible that the earth's surface has been illuminated by the sun many times ten million years. And when finally we consider underground temperature we find ourselves driven to the conclusion that the existing state of things on the earth, life on the earth, and all geological history showing continuity of life, must be limited within some such period of past time as one hundred million years."

We have passed in rapid review the evidence upon which guesses, more or less plausible, as to the age of the world, have been founded. Whatever may be the opinion at which men will ultimately arrive, it cannot but be satisfactory to note from how many quarters and in how many ways Natural Science has in latter days cast light on the inquirer's path.—*Quarterly Review.*

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# THE LOCAL DISTRIBUTION OF PLANTS AND THE THEORY OF ADAPTATION.

By LESTER F. WARD, A. M.

THERE is one class of facts in the geographical distribution of plants which has not received, at the hands of botanists, the degree of attention which its importance justifies.

I do not refer to those wide general phenomena which a comparison of the floras of different countries renders so striking, and by which the more humble and restricted class to which I would call attention is usually eclipsed. Such general considerations are, it is true, exceedingly interesting and important, and are in no danger of receiving too much attention. Nothing could be more absorbing than a close comparative analysis of the vegetation of different hemispheres, continents, islands, and zones, of the globe. The most casual survey of such fields reveals marvels, the mere acquaintance with which excites in the mind of the botanist the liveliest interest and pleasure. The strange and leafless euphorbias of South Africa, with their naked, green, parenchymous branches; the equally singular and grotesque cactuses of America answering to them; the anomalous vegetation of Australia, with its shadeless forests due to their vertical foliage; the absence of oaks east of the Ural Mountains, and of heaths on this side the Atlantic; the confinement of the genus *Rosa* to the northern and of the genus *Calceolaria* to the southern hemisphere—these and numberless other kindred facts connected with the general distribution of plants over the globe are justly calculated to excite the most intense interest, and have given rise to a variety of theories designed to account for them.

The phenomena, however, to which I would more particularly refer, come much nearer home, and may be presumed to have attracted the attention, more or less forcibly, of every one at all conversant with plants. They constitute a distinct class, and may be described in general terms as facts unfavorable to the received theory of adaptation.

It has long been regarded as a law of life, applicable alike to animal and vegetable forms, that each species is exactly adapted to the particular habitat where it occurs; and naturalists, assuming this law, have sought to solve the problem how this remarkable adaptation has been brought about, instead of pausing to question the alleged law of adaptation itself. And yet there have never been wanting numerous and obvious facts, especially in the vegetable kingdom, which, if interpreted at all, must be conceded to be incompatible with such a law, at least unless materially modified and greatly enlarged.

Mr. Thomas Meehan has remarked the fact that "almost all of our swamp-trees grow much better when they are transferred to drier places, provided the land is of fair quality. He referred, among others, to sweet-bay, red maple, weeping-willow, etc., as within his own repeated observations growing better out of swamps than in them." He further observes that "plants as a general rule, even those known as water-plants, prefer to grow out of water, except those that grow almost entirely beneath the surface."[1]

A great many facts are at hand to prove that those plants which are found habitually growing in wet ground may be easily made to grow in dry ground. The *Iris versicolor* (blue flag), which, in a state of Nature, grows universally in marshes, and keeps perpetual company with *Nuphar* (pond-lily) and *Sagittaria* (arrow-head), is a common occupant of the driest gardens. The *Lobelia cardinalis* (cardinal-flower), which I have found below tide-water mark, is also a common garden-flower, and not difficult to cultivate. Almost as much may be said for *Lobelia syphilitica* (great lobelia). The calla, the caladiums, and the anthuriums, belong to this class, and the list might be indefinitely extended.

But differences of moisture in the soil are not the only ones which are often overcome by natural or artificial changes in the conditions of growth. Most of our prettiest wild-flowers which are found growing in deep, shaded glens in pure leaf-mould, have been captured by florists, and made to thrive as well, and often better, under a cultivation which, with their most faithful efforts to imitate it, must be a complete alteration of their native condition of life. Of such might be mentioned at random the *Trillium* (wake-robin), the *Cypripedium* (lady's-slipper), the *Dicentra* (Dutchman's breeches), the *Uvularia* (bellwort), the *Erythronium* (dog's-tooth violet), etc.

So, too, plants growing under other conditions, as on hillsides, and in open woods or meadows, as the violets, hepaticas, anemones, and others, offer no difficulty to the florist.

These are cases in which the transfer is from apparently more favorable conditions to those less favorable. But similar results follow from a reversal of this order. Plants may be successfully transferred to ordinary garden-soil from localities which we would naturally suppose to be less favorable to growth, but to which these seem to be specially adapted. The columbine (*Aquilegia*), which grows on rocks, often with scarcely any soil in which to root, or emerges from narrow

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[1] *See* POPULAR SCIENCE MONTHLY for May, 1874, p. 126.

crevices between them, is planted in gardens where it thrives equally well. The same is true of the *Cacti*, which, taken from the arid plains where their indurated watery stalks and branches store up the water which the climate so long denies them, thrive under cultivation with undiminished vitality. The *Agave*, or American aloe, furnishes a similar illustration, and every few years a gorgeous century-plant blooms under cultivation, to the infinite delight of its owner.

Equally striking results take place under the influence of man without his design or selection. There are a great many indigenous plants which are rarely found outside of the influence of human cultivation. They emerge from their obscure natural retreats at the approach of civilization, spread rapidly over fields and pastures, and often become formidable enemies of the farmer and the gardener. Under the general name of weeds they are proscribed and pursued, and no effort is spared for their extermination. They also invade towns and cities, overrun vacant lots, disfigure parks and plats, and force themselves into pavements and "crannied walls." *Ambrosia trifida* (the great rag-weed) forms forests in waste grounds and neglected gardens. *A. artemisiæfolia* (Roman wormwood) is one of the farmer's most persistent pests, and resists all efforts at extermination. The cocklebur and thorny clotbur (*Xanthium strumarium* and *X. spinosum*) warn us of their disagreeable presence wherever we go. *Polygonum aviculare* (knot-grass) and other species invade our door-yards and threaten to cross our thresholds. *Euphorbia maculata* (spotted spurge) spreads its prostrate and symmetrical mats over the dry and gravelly walks. *Spergularia rubra* (sand spurrey) unfolds its rosy petals to the hottest July sun upon the parching bricks beneath our feet. *Erigeron Canadense* (horse-weed), *Epilobium angustifolium* (great willow-herb), *Gnaphalium polycephalum* (common everlasting), and a host of other indigenous weeds, overrun the cultivated fields and commons wherever man has impressed his influence upon primitive Nature.

This phenomenon, however, becomes still more obtrusive when we turn to introduced species. And, if it be claimed that the transfer from waste places in the Old World to similar waste places in the New is not a change of conditions, we have only to remove our point of observation to Europe or Asia to render all that has been said of indigenous plants applicable also to adventive ones. For, unless we are willing to go further in admitting the transmutation of species than the founders of that doctrine, we must assume that each of these species has had a native habitat somewhere, and its preference for proximity to human habitations is unexplainable on any theory of original adaptation.

Illustrations on this point would be quite superfluous, as these plants constitute the bulk of all our weeds, and present themselves at every turn. I might mention the ubiquitous ox-eye daisy (*Leucanthe-*

*mum vulgare*), the iniquitous Canada thistle (*Cirsium arvense*), and the obnoxious burdock (*Lappa officinalis*), as examples of species which share with man, not only his cosmopolitan character, but also some of his vices. But these foreign immigrants often furnish us with one of the most striking exemplifications of the anomaly, if such it may still be called, which I am endeavoring to illustrate.

It frequently happens that a plant, taken from one country into another having an entirely different flora, thrives more vigorously than it did at home, and even threatens to drive out indigenous species. Some of the species last mentioned belong to this class, particularly the Canada thistle, which, notwithstanding its popular name, has been introduced into this country from Europe, and has spread not only over Canada and New England, but far south and west. *Cnicus lanceolatus* (common thistle) is only less prominent because less troublesome. The same is true of many plants of the mint family, particularly *Nepeta glechoma* (ground-ivy). On the other hand, some American species, like *Erigeron Canadense*, have migrated by the aid of man into almost every country on the globe, always thriving best where civilization is highest. But some of these do not confine themselves to the circle of man's protective influence. Sometimes they strike out into the forest or spread over the plains, carrying dismay to the native vegetation. Mr. Darwin, speaking of the introduction into South America of the cardoon (*Cynara carduncului*), a congener of the artichoke, says: "It occurs in these latitudes on both sides of the Cordillera, across the continent. I saw it in unfrequented spots in Chili, Entre Rios, and the Banda Oriental. In the latter country alone, very many (probably several hundred) square miles are covered by one mass of these prickly plants, and are impenetrable by man or beast. Over the undulating plains, where these great beds occur, nothing else can now live. Before their introduction, however, the surface must have supported, as in other parts, a rank herbage. I doubt whether any case is on record of an invasion on so grand a scale of one plant over the aborigines."[1] He also mentions other analogous cases, though of a character less marked.

This love of change, if I may so characterize it, seems to inhere in the entire vegetable kingdom. Not even climate avails to overcome it, as is evidenced by the rapid invasion from the tropics of many plants whenever the presence of man in any manner creates the conditions favorable to their migration. Conspicuous among these are *Chenopodium* (pigweed), *Amarantus* (amaranth), *Ipomœa* (morning-glory), and others.

If we take a wider view of this class of phenomena, we may perceive that it is only by an extension of the same principle that all the beneficial changes made by man in the vegetable kingdom have become possible. Every plant he has improved and rendered subservi-

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[1] "Naturalist's Voyage round the World," p. 119.

ent to his purposes has become what it is in obedience to an inherent tendency to exchange its original condition for a better one. And it is by taking advantage of this tendency and creating such better conditions that man has drawn it into his service.

This willingness and often eagerness in plants to change their habitat, sometimes without the least acclimation, enlarges, therefore, from the mere *lusus naturæ* which it at first appeared to be, into a law which is coextensive with plant-life. In view of the facts adduced, and others which will occur to the reader, we may conclude that the law of adaptation as popularly held requires extensive qualification if allowed to stand at all; that it is rather apparent than real; that large classes of facts are marshaled against it, and that some wider law is perpetually overruling it. The adaptations of Nature of which we hear so much are *not* perfect. Nature does not provide each species with a habitat best suited to its fullest development. But every plant is at all times ready to change its habitat for a better one, and this is actually going on whenever occasion permits.

Let us now inquire whether the facts enumerated admit of any general explanation. Mr. Meehan proposes to account for the better growth of swamp-trees in drier soil by maintaining that their seeds cannot germinate in dry ground. If this be true, it is a worse commentary on the theory of adaptation than I am willing myself to make without further proof. Certainly no intelligent adapting power could originate so gross and apparently gratuitous an inadaptation as an organism doomed to live out its existence under conditions unfavorable to its healthy development, because, forsooth, it could *begin* its career only under such conditions! But, as both the theory and the commentary rest on a teleological basis, they are both worthless from a scientific point of view.

But, however this may apply to the trees enumerated by him, it certainly does not apply to many plants of the same class which I have named, for florists propagate them from the seed when they choose. Still less can this explanation be admitted to account for any of the other classes from which illustrations have been drawn. And, indeed, I am not aware that any attempt has ever been made to bring forward a rational explanation of a general character for the facts under consideration. Botanists, generally, seem to have been either too much dazed by the light of those more universal and striking features to which attention was called at the outset, or too intent on the special study of the facts themselves, independent of the lessons they inculcate, to have worked out a solution for the problem I have been seeking to present. But the chief obstacle, after all, to such a solution, is to be found in the satisfaction which every one seems to feel with the old explanation, viz., that plants grow in particular places because they are adapted to them and to no other, which, as we have seen, is opposed by a strong array of facts.

In this theory of perfect natural adaptation, whether it be left to stand upon its old teleological basis, or be placed, as some modern investigators would place it, upon a genetic one, a very important factor has been left out, viz., the influence which plants exert upon one another. Adaptation, as the term is employed, is applied to a supposed correlation between the plant and its *inorganic* environment; and to this alone is attributed their entire local distribution. But facts of the class above considered prove that this is not only an inadequate explanation of such distribution, but that it is in many cases no explanation at all, since they so generally disregard inorganic conditions, and thrive equally well or better under entirely different ones from those which Nature furnished. Their distribution must, therefore, be almost entirely attributed to some other conditions; and to what other conditions are they subjected but to organic ones, to those which they reciprocally impose upon each other? It is to these organic conditions, then, to the mutual influence of different kinds of vegetation, growing, as it always does in a state of Nature, in close local proximity and contact, that we must look for the chief laws that control the local distribution of plants.

The modification, therefore, of the adaptation theory, or rather the substitute for it, which, in the light of these facts, I would propose might be called the law of *mutual repulsion*, by which every individual, to the extent of its influence, repels the approach of every other and seeks the sole possession and enjoyment of the inorganic conditions surrounding it—this mutual repulsion results at length in a *statical* condition which is always brought about through the action of the vital forces themselves, and which, as soon as reached, determines absolutely the exact place and degree of development of each species and each individual.

It is this statical condition which is apt to be lost sight of in the modern philosophy of evolution. The modification of species, the survival and advancement of some and the depauperating and extinction of others, all forms of variation and transmutation—these are *dynamical* phenomena, and only take place under the influence of disturbing agencies. Changes of this kind are slow and secular, and lie beyond the reach of direct observation, perceptible only to the eye of reason on the closest comparison of large masses of dependent facts. They, therefore, long escaped observation, and Nature remained until recent times a sealed book with respect to them. What wonder, then, that this still deeper and more occult law of biological statics should have remained still longer undetected, or only dimly seen? For, underlying this dynamical movement in organized beings, there must exist a universal statical condition throughout organic as throughout inorganic Nature.

The changes of which science has at length caught a glimpse can be nothing more than the regular and cyclical or fitful and spasmodic disturbances of a deeper and universal state of forced equilibrium, which pervades the vital as it is known to pervade the mechanical world. And just as astronomers and physicists, confining their investigations to the more obvious and perceptible motions of celestial and terrestrial bodies, long remained ignorant of the law of gravitation which constantly forces all things into a state of equilibrium, so in biology the statical condition has been lost sight of in the effort to obtain better views of that moving panorama which a broader knowledge of the phenomena of life so unmistakably unfolds. Yet, without a clear recognition of this statical law, it is impossible to account for the facts presented by the distribution of plants, and it will doubtless be found equally essential to the full comprehension of many other phenomena of Nature. But, when we recognize this law, the whole aspect of our question is changed. Plants appear to be no longer in a state of perfect adaptation to their surroundings.

There is no longer a necessary correspondence and correlation between organism and habitat, no longer necessary that rhythmical (almost preëstablished) harmony between species and environment. This need only exist so far as is necessary to render the life of the species possible. Beyond this the greatest inharmony and inadaptation may be conceived to reign in Nature. Each plant may be regarded as a reservoir of vital force, as containing within it a potential energy far beyond and wholly out of consonance with the contracted conditions imposed upon it by its environment, and by which it is compelled to possess the comparatively imperfect organization with which we find it endowed. Each individual is where it is, and what it is, by reason of the combined forces which hedge it in and determine its very form. Each species is the perpetual and inexorable antagonist of every other. The "struggle" is not alone "for existence," it is also for *place*. In the plant races, as in the human, there is a recognized hierarchy, the laws of which are as yet to a great extent involved in mystery. But the first principle, as in the rest of Nature, is force. Each one encroaches with all the power of vegetal growth upon its neighbors. This pressure is enormous. Who shall calculate this subtilest of molecular forces? Yet there is no displacement, no motion. So thoroughly has every nook and chink been filled that there is no room for motion. Like the all-pervading circumambient air, its power is not felt so long as no vacuum is produced. Each organism has long since reached the limit of its power to extend its dominion. The plant grows up from the germ to maturity under a constant surveillance, and every attempt to overstep its fixed limits is instantly checked. It stands in its fixed position, locked in the embrace of forces which permit it neither to advance nor retreat.

Such is the state of equilibrium which is always and necessarily reached in a state of Nature, and in which man first finds each newly-discovered flora. But let these statical conditions be once changed, whether by the advent of man or from whatever cause, and this equilibrium is immediately disturbed. The chained forces are set free; a general swarming begins; some individuals are destroyed, others are liberated; each pushes its advantage to the utmost, and all move forward in the direction of least resistance, till at length they again mutually neutralize each other, and again come, under new conditions and modified forms, into the former state of quiescence.

The most frequent and prominent cause of these disturbances of the natural fixity of vegetation is the influence of man. The results of this influence may be said to be the products of agriculture, horticulture, and floriculture, on the one hand, and, on the other, weeds. But there may be many other causes of disturbance besides that produced by man, such as the appearance of new animals, geological revolutions, or climatal and meteorological vicissitudes. Anything which destroys the stability which the perpetually-operating vegetal forces impose upon the plants of any region is certain to reveal a latent vitality, which, when liberated, proves itself capable of profiting by conditions far different from, and superior to, those under which it is originally found. The willow, the alder, the elm, and the sycamore, hug the banks of streams because baffled and beaten back at every attempt to invade the drier ground. The wild-columbine and the saxifrage are driven into their rocky fastnesses by more powerful rivals for the rich forest loams. The thistle and the chamomile flourish in lawns and commons because their human foes are less formidable than the enemies of the plain. The fruit-trees, the cereals, and the roses, reach those wonderful heights of development under man's care, because he not only proves their friend, but wards off all their enemies. And just here it should be remarked that the alleged tendency of cultivated plants to relapse, when neglected, into their original state, upon which Prof. Agassiz laid so much stress as an unanswerable argument against transmutation, becomes, under the law of mutual repulsion, the necessary result of remanding them to their old conditions. As man's care and protection were necessary to enable them to advance, so, when these are withdrawn, they must be expected to again yield to hostile forces, and fall back to the level of their original state. It is not the special adaptation of a plant for the spot on which it grows, so much as the hostile attitude of other plants around it, which restricts and determines its range. The elements which decide where plants shall grow, are to be found in vegetation itself, and not in inorganic conditions. The power of self-adaptation which they possess is sufficient to habituate almost any species to almost any inorganic conditions. Each species, therefore, keeps within its own restricted limits, not because it cannot live in other soils, but because prior occupants forbid it to come.

The law of adaptation may therefore be reduced to this: that every plant possesses the power of self-adaptation to such a degree that, no matter under what conditions it may be compelled, by the higher law of mutual repulsion, to live, it will mould its own organism into harmony with those conditions, and thus continue its existence; and this, whether it is required to adopt a more perfect or a less perfect form.

But what it actually is, is no criterion of what it is capable of becoming, and the locality in which it is found is no evidence that it is best adapted to such a locality. These data only prove that in the final balance of forces to which it is subjected it was assigned such a degree of development and such a habitat.

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# OBSERVING THE INTERIOR OF THE EYE.[1]

By JULIUS BERNSTEIN,
PROFESSOR OF PHYSIOLOGY IN THE UNIVERSITY OF HALLE.

THE retina is the point where the physical process of vision passes into the physiological process. Until it impinges upon the retina, the light which penetrates the eye has only undergone physical changes, consisting chiefly in refraction, the last perceptible result of which is the production of the image upon the retina. From this point the process passes from our immediate observation, and the difficulty of discovering its character increases at each step. The image upon the retina is reversed, and yet we see every object in the field of vision upright. This is the result of the experience, which we have acquired from childhood, in the exercise of the organ of sight. The point *A* (Fig. 1), which is on the right, is imprinted upon the left portion of the retina, and we, therefore, know by experience that a ray, coming from the right, must strike the left portion of the retina; and because we always imagine the objects we see to be external to ourselves, we must do so by unconsciously following the line *a A*, through the optical centre *k*. In this manner the eye projects a uniform field of vision, which is obtained by drawing, from every point of the retina outward, straight lines through the optical centre of the eye, which lines will terminate upon a convex surface.

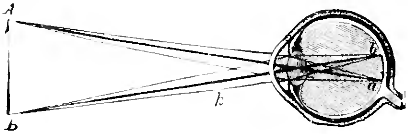

FIG. 1.

This is really the manner in which the eye interprets, in all cases,

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[1] From "The Five Senses of Man," No. XXI. of the "International Scientific Series."

its sensations of sight. For luminous appearances may be produced without our perceiving any external object, but merely a part of the eye or an inward irritation; and yet, in the same manner, we imagine them to be external to ourselves.

If we shut the eye, and press the head of a pin upon the outer edge of the eyeball, we shall see in the dark field of vision a white or colored spot of light, which has the same form as the compressing body. It will be seen upon the left side of the field if the right side is pressed, and upon the upper half if the lower is pressed, and *vice versa.* The retina, therefore, extends as far as the part which projects beyond the socket of the eye, and can be irritated by pressure. It is well known that when the eye is struck a cloud of sparks is seen, which is caused by the mechanical concussion of the retina. These luminous images, often perceived involuntarily, take, speaking scientifically, the form of the body producing the pressure; at the same time we observe the relation between the position of the irritation and the position of the sensation of sight. We transpose a point on the left side of the retina to the right, because we imagine that a ray of light has penetrated the eye from the right, which must fall upon the left half of the retina.

We are also able to perceive particles within the interior of the eye which are found in the transparent media. There are many persons who always see round particles or filaments, which seem to float about in the field of vision. They may be more distinctly seen when looking upon a bright surface—a cloudy sky, or through a microscope. They follow every motion of the eye, and have, moreover, a peculiar motion of their own. These particles are produced by filaments and cells, which may be found floating about in the narrow space between the hyaloid membrane and the retina. They cast their shadow directly upon the retina, which then, from experience, refers them to external objects.

It has also been discovered by more careful observation that the refracting media of the eye are not absolutely transparent, but that a kind of cloudiness is seen in places which throws a shadow upon the retina. If we look at the sky through a small hole in a sheet of paper, held a short distance from the eye, the hole will appear to be surrounded by a colored fringe. This is caused partly by a cloudiness in the vitreous humor, and partly by the peculiar radiating formation of the lens, already described. All such phenomena are called *entoptic*, because they deal with the perceptions of the internal portions of the eye. They are produced by the incident rays of light casting shadows of these particles upon the retina. They are best seen when an isolated pencil of light, like that admitted through a small aperture, is allowed to fall upon the eye; for, in that case, the shadows produced are distinct, while they are generally obliterated in ordinary vision, because the light penetrates the eye from all sides.

One of the most interesting entoptic phenomena is the *Arborescent Figure*, discovered by Purkinje. If, toward evening, we place ourselves opposite a dark wall in a dark room, and move a lighted candle to and fro before our eyes, looking, however, fixedly at the wall beyond, we shall then, after a little practice, see this arborescent figure, whose intersecting branches cover the whole of the dark space, and which is unmistakably caused by the blood-vessels in the interior of the eye. The field of vision assumes a reddish appearance, upon which the veins stand out in dark shadows. The trunk of the figure rises a little on one side of the centre, where the optic nerve enters the eye, and thence branches out after the manner of blood-vessels, which is undoubtedly a proof that in this experiment we see the blood-vessels of the retina itself. One spot alone is free from vessels: the yellow spot, which is the most sensitive to light of all parts of the retina. If, now, the candle is moved to and fro, the figure will also move and follow the direction of the light.

All these observations lead to the conclusion that we are thus enabled to perceive the shadows of the vessels of the retina. That these vessels cast a shadow behind them is clear, but that the shadow should be sufficient to cause a perception leads to the very important and interesting fact that the elements of the retina which receive the impression of light must lie behind the blood-vessels. The diagram in Fig. 2 will explain how the shadow of a vessel can produce an image. If the light is placed at *a* its image will be depicted upon the retina at *b*. At this particular spot no vessels will be seen, because the light is too dazzling. But the image at *b* forms another source of light, and, if there is a vessel at *v*, then its shadow will be thrown upon *c*. Now, the retina projects the image perceived at *c*, outward, through the optical centre *k*, to *d*, where the vessel appears in the field of vision. If the light is now moved from *a* to *a'*, then the image will move from *b* to *b'*, the shadow from *c* to *c'*, and the image of the vessel from *d* to *d'*, thus performing the same movement as the light. We do not, however, generally perceive these retinal vessels, because usually the light falls upon the retina from all

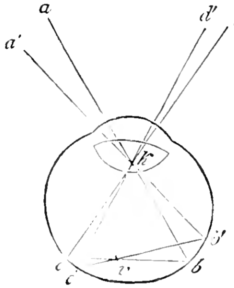

Fig. 2.

points of the pupil, and therefore no distinct shadow can be produced. In the experiment just described the light proceeds from a single point only, *b*, and produces a distinct shadow. Moreover, the light is an unusual one, and throws the shadows upon places which are not accustomed to receive it. This latter circumstance seems to be of some importance, for, if the light is held perfectly still, the figure gradually fades away, because the sensitiveness of the parts of the retina upon which the shadow is becomes blunted; it appears again, however, if the light is moved from side to side, so that the position of the shadow is changed.

A considerable amount of light penetrates the eye through the pupil, which is quite sufficient for the representation of the external world, but none of this light seems to be reflected. The pupil of the eye generally has a dark appearance, so that we cannot see farther into the eye than the iris. It is, however, possible to illuminate the eye in such a manner that all the parts of the retina may be seen. This was first done in a satisfactory manner by the celebrated physicist Helmholtz, the discoverer of the ophthalmoscope. Before describing this apparatus and its functions, we must discuss the fact of the dark appearance generally presented by the pupil.

The amount of light reflected by the background of the pupil cannot, of course, be very great; for the retina alone is able to reflect light, and as it is very transparent, and has, moreover, a dark layer of pigment immediately behind it, which absorbs all the light that has penetrated to it, the reflection must necessarily be weak. We know how difficult it is to see through a window into a room from the street. This is due to the small amount of light which comes through the window, in comparison to that which penetrates the eye from without, so that the eye is not sufficiently sensitive to perceive the weaker impression; moreover, the reflection from the panes of glass considerably increases the difficulty of perceiving objects in the interior of the room. If, however, the room is lighted up at night, we can see the interior very distinctly from the outside, although the illumination of the interior is weaker than it was in the daytime.

These circumstances also apply to the eye; but there is another circumstance which adds to the difficulty of examining the interior of the eye. The same fact makes it impossible to see the background of a camera-obscura through the lens, even when it is white. According to the laws of refraction, both the incident and emergent rays in the eye, or in a camera-obscura, have a fixed direction, while the light which proceeds from a room through the window is diffused—that is to say, emits rays in all directions. Let us suppose an image of a lighted candle to be thrown upon the retina; then, as far as the refracting media of the eye are concerned, this image may be regarded as a second object, the rays from which will take an outward, and therefore opposite direction. Now, this will be precisely the same as the path of the incident rays; for if, at the point where an image of an object has been formed by a lens, we place an exactly similar object instead of the image, then an image will be formed in the exact position of the first object, and of equal size. We see from this experiment, therefore, that the rays of light, which are emitted by an image formed upon the retina, must return to the object from which they originally proceeded.

If, therefore, a light is placed before any eye which we wish to examine, the rays will all be reflected by the eye into the light, and we are unable to intercept them by our own eye, because we should hide the light by placing ourselves between it and the eye under examination. By means, however, of a transparent plate of glass, this obstacle may be overcome, and the eye examined when illumined, in the manner represented in Fig. 3. *C* is the eye under observation, *B* the observer's eye, and the plate of glass, *S*, forms an angle of 45° with the line between the two eyes. The rays emitted by the lighted candle, *A*, strike the glass plate, *S*, and are partly reflected into the eye, which they illuminate. The rays reflected by the eye, *C*, again strike the glass plate, which some of them penetrate, and pass into the eye of the observer, and the remainder return to the light, *A*. The pupil of the eye, *C*, may now be seen brightly illuminated, and even the illuminated retina can be seen more or less distinctly. The rays emitted by the image formed upon the retina, which pass through the glass plate, would form an image at *a*, which is at the same distance from the glass plate as *A*. The rays are, however, intercepted by the observer, *B*, who is thus enabled to examine a part of the retina.

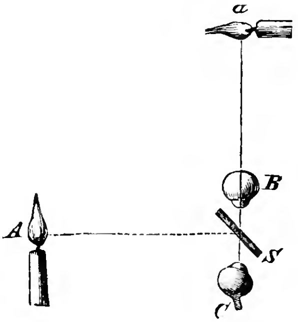

Fig. 3.

In fact, a piece of window-glass placed in an oblique position, as described above, is the simplest form of an ophthalmoscope, and may easily be arranged by any one who wishes to make the experiment for himself. An ordinary piece of glass is sufficient for the purpose, if placed in the same position, relatively to the eye under observation and the light, as that shown in the figure. It is well to place a screen between the light and the person under observation, to prevent any annoyance arising from the intensity of the light. The observer must then place himself close in front of the person whose eye is under observation, hold the glass in the manner described, and move it about till the reflection of the light falls upon the eye. The illuminated pupil will then be seen through the glass, and appear of a reddish color.

But, in order to see the separate parts of the retina distinctly, it is necessary to make use of lenses adjusted to the sight of the observer, and the refractive power of the eye under observation; and the result of such a combination is a perfect ophthalmoscope. The glass, again, has been replaced with advantage by a mirror, generally a concave mirror, with an aperture in the centre, through which the observer looks. Fig. 4 shows the method of using this apparatus, constructed after Ruete's plan. The light is placed near the person under observation, *A*. The rays emitted fall upon the concave mirror, *d*, which reflects them into the eye under observation. The observer, *B*, looks through the aperture in the concave mirror, and moves the two lenses, *m* and *l*, till they are in such a position that a distinct image of the retina appears.

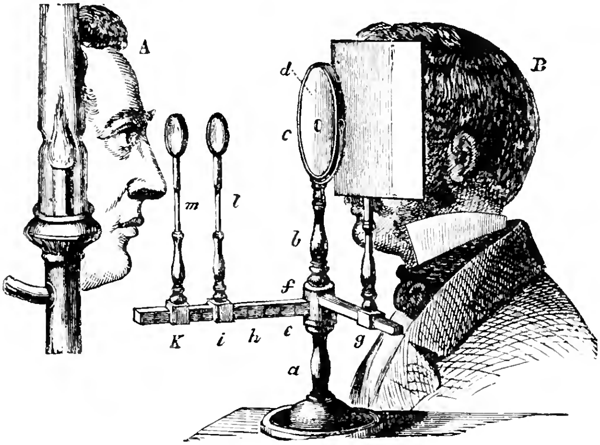

Fig. 4.

We are now in a position, with the aid of the ophthalmoscope, to make a thorough examination of the retina. Fig. 5 gives a tolerable representation of all that we are able to distinguish of the image. The background of the whole is of a dull red, while the point where the optic nerve enters is distinguished as a round, bright spot, and we may see rising out of its midst the retinal vessels, arteries, *a*, and veins, *b*, which extend over the entire retina. The yellow spot also, the point of most distinct vision, may be distinguished as a small bright spot.

The ophthalmoscope has become an instrument of incalculable value to the oculist. Many changes in the retina and interior of the eye, which are due to disease, can be observed and examined by means of the ophthalmoscope; and, in fact, the medical treatment of the eye has made an immense advance since the discovery of this instrument.

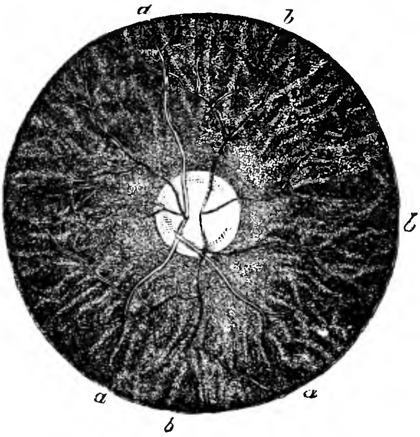

Fig. 5.

The eyes of many animals—those of cats, for instance—exhibit a peculiar brilliancy, which is particularly remarkable in the dusk. It was formerly thought that the eyes of such animals emitted light independently, as it was also thought that light could be emitted by the human eye, under the influence of passion. This brilliancy, however, in the eyes of these animals is caused by a carpet of glittering fibres, called the *tapetum*, which lies behind the retina, and is a powerful reflector. In perfect darkness no light is observed in their eyes, a fact which has been established by very careful experiments; but, nevertheless, a very small amount of light is sufficient to produce the luminous appearance in them.

# SCIENCE AND RELIGION AS ALLIES.

By JAMES THOMPSON BIXBY.

THE antagonism between Science and Religion has become a commonplace of literature. Both preachers and physicists have narrated with bitterness of spirit the battles which they have fought, the wrongs which they have suffered, the complaints which they have to make, the one against the other. The combative have plunged into the *mêlée*, and with slashing pen or tongue given it new asperity and new sources of grievance. The peaceful have endeavored by various reconciling schemes to persuade the combatants to lay down their arms. Historical spirits have searched out and retold the forgotten incidents of the struggle; the philosophic-minded have explored its secret springs. In one way or another all have drawn the attention of the world to the hostile attitude of the two.

Now, it is true that there have been no small number of conflicts between science and religion. But is the whole account of the relation of the two contained in this? Is there not another part to the story? I believe that there is.

Much, it seems to me, might be said in exhibition of the *mutual indebtedness* of science and religion, as well as of their hostilities. Having heard so much of late about the latter, perhaps it may not be unprofitable to consider a little the other side of the shield.

In the first place, religion is much indebted to science. Science has not been a mere iconoclast of everything sacred, but it has been a real helper in the progress of religion.

In the marvelous adventures through which Rabelais conducted his hero Pantagruel, a clime was reached so cold that the words of the men, it is said, as they passed the lips, froze and fell as hail on the deck; but, brought near the fire, the congealed words thawed and gave up their sounds. So, under the sunbeams of science, the dumb matter, the frozen thought of the Creator, melted into intelligible accents and spoke forth its secrets. Sun and cell, magnet and crystal, have each found a tongue and told the world of facts, exhibited to it achievements that, if predicted a thousand years ago, would have seemed like nothing but a chapter out of the Arabian Nights Entertainments.

Now, these triumphs of science have not redounded merely to the empty glory of their hero, but they have been solid contributions also to the benefit of man and to the glory of God.

What other argument for the existence of God has done more for theism than the argument from design? In the admirable harmonies and adaptations of the world, the natural theologian finds the most convincing illustrations of a Supreme Intelligence anterior to the universe. Whence is it that a knowledge of these instances of contrivance and order has been obtained? Plainly, it is from the scientific study of Nature that the overpowering strength of this argument has been derived. Ordinary observation—to be sure—would, of course, first suggest the argument and present not a few illustrations. Three thouand years ago the Psalmist put those forceful questions—"He that planted the ear, shall he not hear? He that formed the eye, shall he not see? He that teacheth man knowledge, shall not he know?"

Here lies, indeed, the gist of the whole argument from design. Yet it is to modern physical investigations, in anatomy, chemistry, natural history, that we owe those exquisite illustrations of curious adjustment and interdependence that in the hands of a Paley or a Sir Charles Bell have given the design argument such force and sweep. Compare the proofs of God's unity and intelligence open to a David or a Paul with those which Prof. Cooke finds in chemistry, or Winchell in geology, or Agassiz in natural history, and how much more manifold and marvelous the latter!

In the next place, science has been most helpful to religion in purifying its faiths and guiding its reverences. Now, this is a service that Faith much needs to have some one to do for her. For, sublime as are her aspirations, her intellectul vision is but dim. Her eye fixed on the heavens to which she would climb, she cannot discern distinctly the steps by which it is reached. She needs science ever to be at hand to direct her. In her mounting instinct, Faith stretches up her hand and clutches and clings to whatever she comes across. The misshapen tree which rescued the savage from the wild beast; the black stone which fell from the sky; the serpent or the crocodile whose strange form and power fascinate the primitive man—such are the objects that humanity, in its first dim gropings for an object of worship, embraces. Religion may remain long in this groveling stage, as it did among the Egyptians and Assyrians. But sooner or later, as knowledge increases, the powerlessness and the worthlessness of such things for the worship of thinking men are seen. Faith reaches up her hand to higher objects—the invisible but potent wind, the outstretched sky, the ethereal fire, the sun that warms and lights the whole earth. These are looked upon as mighty living beings, and venerated in solemn rites. But, again, as man learned more of these—the fixed laws which they obey—the confined paths in which they move, and, in learning this, learned more of himself—he recognized in conscious Intelligence and the overruling Will something greater than wind or fire. Faith raised her reverence, then, to a divinized humanity, a company of human gods—Jove, king of heaven, and Juno, queen; Mercury, messenger of the gods; Cupid, inspirer of love; and so on. But, again, with the growing comprehension of the unity of all Nature, man rose to the idea of a single supreme deity, a Jehovah—the eternal I am—Brahma, the one reality, of which all else are masks and shadows—and thrust down the other deities into the position of divinities, spirits, and devils. Still Religon had not got above superstition. She still clung for a long time to burnt-offerings, and washings, and fastings, macerations, and masses; interferences by good and evil spirits; ideas of God as jealous, wrathful, appeasable, repenting of what he had once done, interposing to mend his work. Gradually-increasing knowledge pulled one after another of these rounds also out of the hands of Religion, and her yearning fingers that must clasp something reached up still higher on the ladder of divine apprehension, until at last she grasped the conception of the universal, eternal action of One Infinite

Perfect Being, without parts, without partiality, and without shadow of turning, to be worshiped only in spirit and in truth.

Science, to be sure, in this process of purification, has destroyed a great deal that has been very dear to Faith. It has uprooted old ideas and pulled down about our ears accepted systems—both physical and spiritual systems. The change in our views of the world has been most radical.

What was the conception of the world held by the orthodox churchman of the middle ages? The earth was a square plain, at whose outer edges rose mountain-walls, supporting the vault of heaven. This vault was a solid crystal roof, wherein the fixed stars were set, and over which moon and sun were pulled to and fro by the angels. Above this firmament, separating the waters which are above from the waters which are below, was the celestial cistern through whose windows the rain fell. Above this, again, the seven-storied heaven, in whose highest story dwelt Jehovah himself, seated on his throne of glory, surrounded by angels and saints.

To-day, how has science stretched out this little cosmos! The astronomer has turned his telescope upon that adamantine firmament, and it has dissolved into thin air. The total solid particles that the blue expanse contains, it has been estimated by Tyndall, might probably be packed into a lady's traveling-bag. The glittering points that gemmed its surface have expanded into enormous suns—thousands of times as large as our own globe. The circumscribed heaven of the Apocalypse, 12,000 furlongs each way, has spread out, from that one-hundredth part of the cubic dimensions which we now know our own earth to have, into an immensity of space which puts us so far from the nearest fixed star that a locomotive could not reach it in 700,000 centuries; and that even when we had attained this enormous distance we should stand merely at the entrance of a starlight avenue, down whose infinite vista come the rays from still more remote suns! Our own earth, formerly the grand, immovable stage to which the wandering sun and stars were only decorations, has been shriveled into a petty pellet of cosmic stuff, dislodged from its fixed and central position, and sent whirling on its way as one of the smaller satellites in the train of a central body, which central body, though as much larger than it as a cart-wheel is than a pea, is yet but one of more than 20,000,000 suns contained in its own part of space; and is itself not stationary, but moving with its planetary fleet at the rate of 4,000 miles a day round some still larger centre.

And in time, as well as space, has science enormously multiplied the numbers. Where the Bible chronology gave sixty centuries for the world's age, science demands as many millenniums. Where Genesis granted six days for the business of creation, geology requires as many æons. Science has mined in caverns and found man's tools and weapons among the bones of mammoths. It has deciphered hieroglyphics and found arts and history already venerable before the date when commentators admitted that Adam was created. It has learned how vast beds of chalk and limestone, miles in thickness, have been manufactured by microscopic creatures; how from a fiery cloud the globe gathered to a molten ball, and on the molten ball formed the crust that now suspends us above the still furnace-heated interior. Learning little by little all this, science has been compelled to put the date of the cosmic beginning back into an antiquity that, in comparison with the Mosaic work, seems an eternity.

And in thus prolonging the age of man and the world, science has altered our conception of the method by which the universe came into existence. It can no longer be looked upon as created out of nothing, at one grand *tour de force;* but as a process of organization, a process continuous and alike in every atom. In the glowing, gaseous nebula, in the curdled, nucleated fire-mist of the embryonic star, in the more consolidated, but still molten, heaving mass of our sun, in the ring-girt Saturn, the still steam-enveloped Jupiter, the sunny summer-time of our own planet, are discerned by the modern physicist the various stages through which every planetary system passes. From the heterogeneous to the homogeneous, from the diffused to the compacted, from the unorganized to the organized, from the lifeless to the living, this is the eternal rhythm of the cosmic evolution.

The cosmic evolution! Yes, this is the further and mightier change which science has made in our conceptions of the world's government. In the current belief of Christendom even 200 years ago, this earth was a world of decay and supernatural intervention, ever to be dreaded. Powers of darkness were struggling with the powers of light in ceaseless efforts for the mastery. Close underneath the earth's surface were the fiery pit and the gloomy realms of purgatory. Through caverns and secret ways mischievous devil and perturbed spirit passed up and down. The graveyards were haunted by ghosts. A comet foreboded disaster to nations, and an earthquake was the overture to the judgment-day.

By a compact with Satan a sorcerer could blight the harvest, or lay low whomsoever he wished with fatal disease. Ordinary phenomena, of course, were supposed to take place as the result of the natural arrangements instituted at the creation, but whatever was at all out of the usual order was looked upon as a special intervention, either of saint or magician, imp or angel, Satan or God, according to its respective evil or goodness, littleness or greatness.

All this science has ejected from the belief of enlightened men. Instead of a fall of the human race, and increasing ruin in the world, science has shown the gradual upclimbing of the race from cave-dwellings and garments of skin to the luxuries and enlightenments of our present civilization. Men of science have been over the whole earth and scrutinized the whole heavens, exploring every dark corner and strange event. Their best instruments have caught sight of no devil, their deepest mining-shaft has reached no limbo of departed souls. They have traced beforehand the path that the comet would pursue, found the cause of the earthquake, the connection of disease with its physical antecedents and antidotes. Spectres have been reduced to illusions of the visual organs, and lunacy to affections of the cerebral lobes. The witches and imps of the old dispensation have vanished before the light of modern knowledge like shadows of a hideous night. Interruptions of the established order, whether by wizard or holy exorcist; special dispensations and interventions, whether from the realm of *diablerie* or providence, are no longer credited; but law, inflexible law, without the slightest slip or variation, is believed to reign always and everywhere. Lily and solar system unfold according to one and the same formula. The hallucination of the senses, the insane delirium, these also have their natural sources from which they flow in a regular order. Even in the exception lies hidden some deeper law.

With such a strong and iconoclastic hand has Science plied the axe in the domain of Faith. As every one knows, it has been exceedingly painful to many pious souls. It is charged that these reconstructions which modern inquiry have made and are making unsettle all the foundations of religion; that they strip off the bloom of mystery and sacredness from the flowers of faith and conduct to irreverence. Are they, in truth, to be deplored? It seems to me that they are not, but to be rejoiced at. It is true that they have given the death-blow to many forms of faith. It is true that they have disabused us of many ancient venerations. To-day, when we carry flame sealed in our vest-pocket ready to come forth at the scratch of a match, no fire-deity, of course, receives any longer the sacrifice of our first-born. To-day, when we bottle up the lightning and make it our errand-boy, we no longer revere it as the bolt of Jove. But for everything that Science has taken away from Religion, she has given her something greater. If she has weaned her of her blind awe of the unknown, she has substituted a more rational awe of the known. If with ruthless hand she battles down every baseless tradition and fond illusion, she consecrates with religious veneration the simplest real fact. If Nature no longer is the object of human dread, yet, as the useful storehouse whence we draw food and treasure, as the friendly Titan who performs for us tasks beyond our unassisted power, it holds a higher place. If the astronomer's lens has dissipated the ancient heavens, it is to show us system behind system of celestial bodies, blazing at immeasurable intervals in the depths of illimitable space. If geology has taken away the idea of a creation finished once for all in a certain six days of the year B. C. 4004, it has given us instead a continual process of moulding and perfecting carried on for 100,000,000 years. The rigorous probing that science has given to Nature does not remove any of its wonderfulness, any of its perfection, but rather has disclosed new marvels behind those which first struck man's attention. The widening of the circle of the unknown has only served to confront us with deeper and deeper mysteries. Science has ruled out miracle and magic from the order of events, but it is to pick up the wizard's wand itself, bring up before us daily stranger and grander phenomena, only the more inexplicable and amazing because of the certainty we feel that somehow there is no exception in them to our most ordinary experience.

Science has expelled witch and elf, nymph and demon, and thus depopulated the supernatural world; but in the place of this uncanny brood, the thought of whose capricious intervention paralyzed the will and debauched the heart, the universe has been filled with the presence of *One*, Eternal and Infinite, from whose perfect law we can never escape. The more clearly we discern the path on which science has led the world, the less fear shall we have that it is all a preparation for precipitating us into some godless abyss. Put the case squarely before any one in its full significance, and there is no one, I think, who would prefer to go back to the cosmic baby-house of the middle ages. Who would vault in again the immensity of space? Who would cut down to six ordinary evenings and mornings the activity of Him who inhabiteth eternity? Who would relinquish the confidence and hope inspired by the unswerving progress of that single divine purpose that links the ages together?

Thus has science given to the cause of faith assistance which more than countervails whatever injury it may have done.

And so has Religion also, in reality, helped science—helped, I believe, even more than she has hindered.

It is to the understanding that the great achievements of physical inquiry are commonly referred. Science is spoken of as a domain of dry light and clear-cut facts, and religion is contrasted with it as the realm of emotion. But how could the intellect have ever gained its great victories without the aid of the heart? how could the senses have ever penetrated into Nature as they have done, had they not been carried on the wings of the spirit? What could science accomplish without the emotions of enthusiasm and devotion, the instructive feeling of truth and beauty, the love of Nature for its own dear sake? "It is in vain, I think," said Prof. Tyndall, at London, in 1869, "to separate moral and emotional nature from intellectual nature. Let a man but observe himself, and he will, if I mistake not, find that, in nine cases out of ten, moral or immoral considerations, as the case may be, are the motive force which push his intellect into action." The reading of the works of three men, he proceeds to say—Carlyle, Emerson, and Fichte—neither of them friendly to the scientific spirit, carried him victoriously through mathematical studies and physical investigations, and made him the man of science that he is. To the same effect is the striking declaration of that other great leader of scientific thought of to-day. "The great deeds of philosophers," says Prof. Huxley, "are less the fruit of their intellect than of the direction of that intellect by an eminently religious state of mind."

Consider the characteristics demanded in the successful study of Nature, and we shall discern the spiritual source whence these physical triumphs come.

One of the first requisites in the inductive method is the humble-mindedness that will completely submit itself to the evidence of the facts. "Access to the kingdom of man, which is founded on the sciences," Bacon aptly says, "resembles that to the kingdom of heaven, where no admission is conceded except to children."

Another condition of success is the spirit of industry that is unswerved by love of ease or idea of labor's dishonor. Another, again, is the candor that will look on all sides of a case, and listen to every objection—consecration to truth as the primary object. These are the qualities which men of science set forth as the requisites for walking within the veil of the temple of Nature.

But what else are these than the very graces of Christianity? Take the childlike mind that the founder of the inductive method demands: it is just what Christ enjoins. Take the fearless love of truth that seeks the absolute facts—the cause behind the cause. How long would it hold on its way did not spiritual aspiration ever feed its secret springs with the insatiable hunger after perfection? Take that diligence in labor and honorable estimation of work which is one of the essential instruments of scientific work, and ask what is the impulse that has endowed modern Christendom with it. "Labor," as a German writer of weight has well pointed out, "was considered by our heathen forefathers a dishonor; and even in the present day, where the gospel is not preached, the stirring disposition, the assiduity, the spirit of enterprise in the people, is disproportionately less. The duty and dignity of work is one of the priceless gifts to modern science of him who said, 'My Father is working up to this time, and I work.'"

Or consider that interest in Nature that is such a powerful spring of physical inquiry. Consider that sacred claim of his vocation which the true servant recognizes—such a sense of it as leads a Lyonnet to spend his life counting the 40,000 muscles in a caterpillar's body! Is it not the Christian spirit, the belief, that is, in the brotherhood of man and the duty of self-sacrifice—the feeling of filial loyalty to a Divine Father, all of whose works are significant, and all of whose service is noble—that, as much as or more than anything else, has given birth to it?

It is a singular fact that the Greek and the Roman, in spite of their great intellectual acuteness, accomplished so little in the penetration of Nature's secrets. With the strong love of the beautiful that distinguished the one, and the profound sense of law that marked the other, one would have supposed that they would have felt more the charm and loveliness of the outward world, and have taken a greater interest in discovering its unchangeable ordinances. Is it unreasonable to refer much of this to that difference of religion which constitutes the most striking distinction between the classic and the Christian world? In the first place, the selfish isolation, the jealous individualism of ancient life, gave no encouragement to that sense of common interests among all mankind which is the justification of the scientist's pecuniarily unprofitable labors. Among the Greeks, while the feeling of devotion to the state, or rather city, was intense, the sentiment of the general welfare or the cause of humanity hardly existed. It was only with the advent of Christianity that the idea of mankind as one great family, each one of whom must labor for all the rest, came in. This idea has been the nurse, not only of modern civil freedom, but of modern science. "Not till the word barbarian was struck out of the dictionary of mankind," says Max Müller, in his "Lectures on the Science of Language," "not till the right of all nations of the world to be classed as members of one genus or kind was recognized, can we look even for the first beginning of our science. This change was effected by Christianity."

The grand thought that accompanied this sense of human brotherhood, forming the other pole of gospel truth, viz., the belief in one God and Father of men, gave an equal contribution toward supplying the intellectual soil needed for the prosperous growth of science. With the multitude of national and local gods, and even tribal or family divinities, which prevailed in the classic world, the minds of men were constantly diverted from that unity that is the scarlet thread in every royal cable of science. But monotheism, establishing unity in the divine realm, gave unity also to the order of Nature. While surrounding nations looked upon Nature in dread, and in blind superstition sacrificed their own little ones to the meteor or the volcano, the Hebrew, tracing all things up to the power of the eternal *I am*, beside whom there is no other god, found in all the forces and marvels of Nature fountains of good cheer and grateful praise. The earth was "the Lord's and the fullness thereof." "Dragons and all deeps, fire and hail, snow and vapor, stormy wind, fulfilling his word —all these were to praise the name of the Lord. For he commanded and they were created. He hath also established them forever and ever; he hath made a decree which shall not be moved" (Psalm cxlviii.). Christianity took up and diffused this grand view of the relation of Nature to God and to man. Though the appreciation of Nature's beauty, order, and dignity, was swamped for a time by the tide of Oriental asceticism, Grecian metaphysics, and transformed polytheism, it rose gradually above it, and established itself firmly in the mind of Christendom. It is this new interest in all the aspects, changes, and laws of the material, vegetable, and animal realms, full as much as the propounding of the Baconian method, that has so adorned physical knowledge in these latter days; and when we consider what gave this new attraction to Nature, and shed over it a divine light, as it were, we can find no other agency so conspicuous, so powerful, as that of the two great religious dispensations, the record of which has been preserved for us in the Old and New Testaments. One whose name is among the very first on the rolls of science has given strong and explicit testimony on this point. Alexander von Humboldt, in a striking passage of his "Cosmos," sketching the intellectual phenomena of this world, thus describes the state of the Hebrew mind as distinguished from that exhibited among other portions of the human family: "It is characteristic of the poetry of the Hebrews that, as a reflex of monotheism, it always embraces the universe in its unity, comprising both terrestrial life and the luminous realms of space. The Hebrew poet does not depict Nature as a self-dependent object, glorious in its individual beauty, but always as in relation and subjection to a higher spiritual power. Nature is to him a work of creation and order—the living expression of the omnipresence of the Divinity in the visible world. Hence the lyrical poetry of the Hebrews, from the very nature of its subject, is grand and solemn, . . . and develops a rich and animated conception of the life of Nature. It might almost be said that one single psalm represents the image of the whole cosmos. We are astonished to find in a lyric poem of such limited compass the whole universe. . . . Similar views of the cosmos occur repeatedly in the Psalms, and most fully, perhaps, in the ancient if not ante-Mosaic book of Job."

Thus did religious reverence among the Hebrews lead to the notice and study of Nature. And, as to its influence on modern culture, let us listen again to the great philosopher of Berlin: "When the feelings died away," he continues, "which had animated classical antiquity and directed the minds of men rather to a visible manifestation of human antiquity than to a passive contemplation of the external world, a new spirit arose. Christianity gradually diffused itself, and, wherever it was adopted as the religion of the state, it not only exercised a beneficial condition on the lower classes by inculcating the social freedom of mankind, but also expanded the views of men in their communion with Nature. The eye no longer rested on the form of the Olympic gods. The Fathers of the Church, in their rhetorically correct and often practically imaginative language, now taught that the Creator showed himself great in inanimate Nature no less than in animated Nature; and in the wild strife of the elements no less than in the still activity of organic development. It was thus the tendency of the Christian mind to prove from the order of the universe and the beauty of Nature the greatness and goodness of the Creator, and *this tendency to glorify the Deity in his works gave rise to a taste for natural observation.*"

He who would assign, then, the sources of the modern scientific spirit cannot, without injustice, fail to assign a large measure of influence to Christianity.

Besides this general assistance to science from the religious spirit, the Christian Church, as an organization, although guilty of much hinderance, nevertheless has given much help. I believe, indeed, that in an impartial comparison the assistance which it has supplied would outweigh the injury which it has done. There was a time in the history of Europe we should not forget—when the fruit of all past knowledge and the seeds of future culture and enlightenment lay in the hands of the Christian clergy. For six centuries during the deluge of barbarism and ignorance which had submerged the ancient world, the Christian Church was the ark which rode upon the flood, bearing in its bosom whatever was most precious of the old-time learning and knowledge. Amid the devastations which attended the repeated waves of barbarian invasion, the greater part of Italy and France had become desolate and waste, dense with tangled forests, and haunted by wild beasts; and the arts of agriculture were not merely disused, but almost forgotten. By whom were these tracts and arts in Western Europe recovered for civilization? Mainly by the monks and priests. It is calculated that three-eighths of the cities and towns of France were born under the pioneership and protection of the monastic orders. The Benedictines, Mrs. Jameson says, were the first agriculturists who brought intellectual resources to bear on the cultivation of the soil, to whom we owe experimental farming and gardening, and the introduction of a variety of new plants.

Again, in the disorders occasioned by the fall of the Roman Empire, the imperial schools formerly scattered over Western Europe were extinguished, for an almost universal loss or destruction of books had occurred. It was only in the cloister and in the schools attached to the monasteries, established primarily for the study of the Scriptures, and conducted by the monks, that the light of knowledge was kept alive in Western Europe. The great universities of Europe, such as those of Paris, Bologna, Oxford, and Cambridge, are generally admitted to have had their origin in the schools attached to cathedrals and monasteries. Almost every one of the ancient and eminent seats of learning was either founded by the clergy or originally instituted for the purpose of fostering the study of the Scriptures.

Of course, the studies which occupied the first place were the Bible, the works of the Fathers, and theology in its various branches. But they were not limited to these. Science and art received attention, as well as sacred literature. Physics, chemistry, botany, medicine, law, painting, and the art of illumination, were all pursued within the walls of the cloister. A Benedictine monk, Guido d'Arezzo, was the inventor of the gamut, and the first who instituted a school of music. The monks, it is claimed by high authorities, "were the parents of Gothic architecture, the inventors or improvers of the implements used in painting, the discoverers and preparers of some of the finest colors." "As architects, as glass-painters, as mosaic-workers, they were," says Mrs. Jameson, "the precursors of all that has yet been achieved in Christian art." Many of the distinguished pioneers of science belonged to the Church, or were educated in it. Among the alchemists, the forerunners of our chemists, Roger Bacon, Thomas Aquinas, Albertus Magnus, Raymond Lully, were ecclesiastics. Giordano Bruno in his early life was a Dominican priest; Gassendi and Copernicus held church offices, the former that of Professor of Theology, and afterward *prévôt* of a cathedral, and the latter a canonry and archdeaconship, and both remained faithful churchmen throughout their lives. Kepler was educated at the school of the monastery of Maulbron, and Boerhaave studied at Leyden for the sacred profession. This list, which a little research would easily enlarge, shows that, if there was a current in the Church antagonistic to scientific investigations, there was also a current that sympathized with it and impelled it onward.

Thus have science and religion given to each other assistance which more than balances, it seems to me, whatever hinderances they have put in each other's way. This assistance, to be sure, has been imperfect, has been more or less unconscious, and sometimes, perhaps, in despite of what has been intended. In the present controversy, as to the proper relations between science and religion, does not this page of history give useful instruction? Not to render them opponents, or maintain conflict between them by raking over the ashes of controversy; not to patch up a temporary truce by schemes for dividing the field of knowledge between them, but to continue and perfect between them this alliance of the past, making it henceforth a conscious, entire, and welcomed coöperation—is not this the duty of the present and the future? Since neither science nor religion can claim an exclusive sovereignty over the field of knowledge; since that domain cannot well be partitioned off between them, the true way is to unite them in a perpetual alliance. Take the testimony of both religion and science. Presume that there is a certain proportion of truth in what each has to offer. Weigh in the scales of reason what each presents. Accept that which is most solid, from whichever side it comes; or if neither, which is likely, presents the whole and real fact, employ the parallax of the two to give the actual position and full form of the two.

Each should seek from the other correction of its errors and filling out of its imperfections. Religion ought to obtain, from wider knowledge, greater purity and enlargement. She ought to learn from physical discovery the importance of going at once to facts and thoroughly studying them, instead of sitting in her study patching dogmas out of scriptural shreds. She should learn from science the method of studying facts, as well as its importance, how to criticise, to sift, to throw away the chaff and keep only the solid grain. And, having mastered the secret of modern knowledge, she should proceed to put theology upon a solid inductive basis, and build it up into the genuine science of which it is capable.

And similarly science ought to obtain the help of religion to elevate and perfect it. From the ideal aspirations of faith science should enlighten its vision and ennoble its aims. It should not restrict its studies merely to the lower realm of facts. Science fails to fulfill its appointed mission in the world if it ceases its researches on the threshold of the grandest discoveries open to it, the questions above all in interest to humanity. It should learn from theology to study the laws of mind and soul as well as those of matter; to recognize that the fundamental truths of morality and religion are self-evident, as well as those of geometry, and that the belief in a God and in a future state is as primitive, universal, and necessary, as the belief in the uniformity of Nature or the indestructibility of force. It should look at the upraised finger of Faith and be pointed from the law to the Law-giver; from the effect to a cause; from the force to the living well.

To widen, purify, and make stable; to save from the building of unsubstantial air-castles, and from blind clasping of objects unworthy of worship—this is what science should do for religion.

To inspire and enable and crown; to turn from peering and picking altogether in the dust; to look up to the heavens—this is what religion should do for science. Playing no hostile nor rival, nor even independent strains—but each in sweet concord and divine respondence, joining in the same holy anthem—thus knowledge and reverence, mind and soul, all "according well, may make one music as before, but vaster."

# NATURE OF THE INVERTEBRATE BRAIN.

By Prof. H. CHARLTON BASTIAN.

## I.

NOTHING distinctly answering to a brain is to be found in the lowest animals in which a nervous system exists. It is thus, for instance, with star-fishes and the larger nematoid entozoa, in which what most nearly resembles a brain consists of a mere band of nerve-fibres surrounding the commencement of the œsophagus, and containing a few nerve-cells, partly between its fibres and partly in groups slightly removed therefrom.

The absence of distinct ganglia in the neighborhood of the mouth in star-fishes is doubtless due, in the main, to the form of these animals, and their low type of organization. Each arm or ray presents its own nervous system, and the ring or band round the mouth seems to be little more than a commissure connecting these otherwise distinct parts of the common system.

In the larger parasitic nematoids the nervous system is more concentrated. The œsophageal ring and immediately adjacent parts constitute almost all that is known of the nervous system in these organisms, and it contains, or is in relation with, a larger number of ganglion-cells than the similar part in star-fishes. Thus, in addition to the cells intermixed with the fibres of the ring itself, there are five or six groups adjacent to and in connection with it, which receive fibres from certain large papillæ surrounding the mouth and having a rudimentary tactile function. These papillæ are, in all probability, the nematoids' principal sensory organs. By means of the connecting nerve-fibres and ganglion-cells they are brought into relation with the nervous ring, and from this other outgoing fibres are, doubtless, given off to the four great longitudinal muscular bands by which the movements of the animal are effected. The distribution of these latter or motor nerve-fibres, however, has not been distinctly traced. The absence of ganglionic swellings on, or in connection with, the œsophageal ring of nematoids is probably dependent upon the comparative simplicity and limited number of impressions capable of being received through these cephalic papillæ.

We turn now to the nervous system, and to those parts of it, more especially, which answer to the brain of higher animals as it occurs in the three sub-kingdoms of the *Invertebrata*, containing its higher types of life. These sub-kingdoms are VERMES, ARTHROPODA, and MOLLUSCA.

Among representatives of the sub-kingdom *Vermes*, the nervous system varies a good deal in minor details, in accordance with the degree of organization, and with the diversity of the sensory and locomotor endowments of the several organisms. The broad features of the nervous system, however, are very similar in all.

The *Nemertidæ*, a class of marine worms, possess a nervous system of very simple type. They have soft and highly-contractile bodies, covered with cilia, but are otherwise wholly devoid of external appendages or traces of segmentation. On the anterior extremity of the body, a little posterior to the mouth, two, four, or more specks of pigment are met with, which are conjectured to serve the purpose of rudimentary ocelli, and while the animal is moving from place to place this anterior part of its body doubtless acts as its principal tactile surface. Nerve-fibres proceed from these regions, and converge so as to form three or four nerve-trunks on each side, which enter a comparatively large ganglionic mass lying on the lateral aspect of the sheath of the proboscis. Each ganglion is pyriform in shape, and connected with its fellow by means of two commissures, one of which passes over, and the other underneath, the proboscis. It is difficult to trace the ultimate distribution of the nerve-fibres in these creatures; so that, although fibres can be followed nearly up to the pigment-spots, none have been detected in immediate continuity with them.

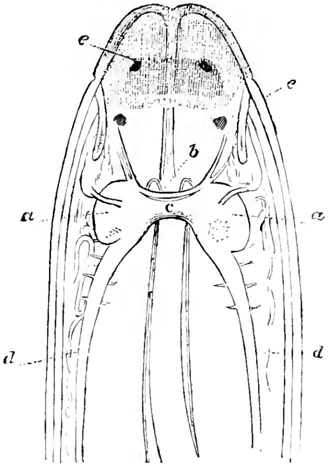

Fig. 1.—Head and Brain of Nemertes.

The inferior commissure between the two ganglionic masses is shorter and broader than the upper, and, while it serves in part to bring the two ganglia into communication, it is also partly composed of commissural fibres, uniting the two great lateral nerve-trunks. These start from the ganglia, and, proceeding along the sides of the body, give off numerous branches to the longitudinal and circular muscles between which they are situated.

The pyriform ganglia are mostly of a pink or reddish color, and they are crowded with small nerve-cells. They represent the brain as it exists in these animals, and we have here, perhaps, a type of the simplest form which this organ could assume among active creatures possessing a distinct bilateral symmetry. Tactile and possibly gustatory impressions, together with impressions produced by light or darkness, doubtless come from the anterior extremity of the organism to the pyriform ganglia on either side, and are thence reflected along correlated channels in the great efferent bundles, proceeding to the muscles on one or both sides of the body, and also to the muscular proboscis. Other departments of the nervous system may exist in these animals, though as yet none have been detected.

In the common earthworm the nervous system is somewhat differently developed. The lateral ganglia of the *Nemertidæ* are replaced by two upper ganglia, connected by lateral commissures with a single lower ganglion; and, as a consequence of the coalescence of the two lower halves, we have, instead of the two lateral cords of the *Nemertidæ*, a double ventral nervous cord traversing the whole length of the body. There are no distinct ocelli in the earthworm. The body is composed of a multitude of ring-like segments, each of which is provided with lateral setæ, which are called into play during the subterranean locomotions of the animal.

The double ventral cord has a fibrous structure along its upper surface, while below there is an irregular stratum of ganglion-cells. These cells are more abundant about the centre of each body-segment, and their aggregation gives rise to a series of rudimentary ganglia in these situations. From every one of the ganglionic swellings two nerves are given off on each side, while a third pair of nerves issues from the cord itself just anterior to the swelling, and is distributed along the anterior boundaries of the segment.

The œsophageal ganglia in the earthworm are, proportionately to the rest of the nervous system, much smaller than in the *Nemertidæ;* and this is perhaps due in great part to the existence of the numerous segmental ganglia in the former, which have no existence in the marine worms. The movements of the *Nemertidæ*, like those of the nematoids, are probably much more exclusively under the control of the œsophageal ganglia than are those of the segmented earthworm —in which each of the body-ganglia doubtless has much to do with bringing about the contraction of contiguous muscles. The earthworm has also a more complex visceral structure than is to be met with among the *Nemertidæ;* and, moreover, it presents more distinct evidences of a nervous interconnection between the different organs of the body and some of the principal nerve-centres. Lockhart Clarke has described a complicated ganglionic network on each side of the œsophagus, starting from the commissures and sending prolongations to the intestine and other parts. By means of this principal visceral system of nerves, the internal organs are brought into relation with one another, and with the nervous system of animal life—that is, with those parts having to do more especially with the relation of the organism to its medium.

The upper or supra-œsophageal ganglia, representing the brain of the earthworm, receive a nerve-trunk on each side, composed of fibres coming from the tactile upper lip, and, as no sensory filaments of a different order are known to be immediately connected therewith, the functions of the brain in this animal must be comparatively simple. This upper lip contains a certain amount of diffused pigment, though there are no signs of the existence of distinct ocelli. I have spoken of the part as a special organ of touch, but it is equally probable that it may be capable of receiving more special impressions representing rudimentary tastes. The separation between these modes of sensibility may in such low organisms be somewhat indefinite.

In the leech we meet with some variations in the arrangement of the nervous system, of a kind analogous to changes subsequently to be spoken of as occurring in higher forms of life. The nervous system becomes more concentrated. There is no longer a ganglion for each segment, but one for every three or four segments of the animal; and the two ventral cords approximate so closely as to be almost fused into one. In the common medicinal leech, for instance, there is a bilobed ganglion (*a*) above the mouth, which receives fibres from the tactile lips, and also ten distinct filaments from as many pigment-spots (*b b*) or ocelli, situated round the margin of this upper lip. From this bilobed ganglion, which corresponds with the brain proper of higher animals, a cord descends on each side of the œsophagus, and the two unite in a heart-shaped supra-œsophageal ganglion (*c*), from which afferent nerves are given off to the muscles whose business it is to move its three saw-like jaws, as well as to the muscles of the oral sucker. This lower ganglion in part corresponds with the "medulla oblongata" of vertebrate animals. It is continuous with the double ventral cord, on which twenty equidistant rhomboidal ganglia are developed. Each of these ganglia gives off two nerves

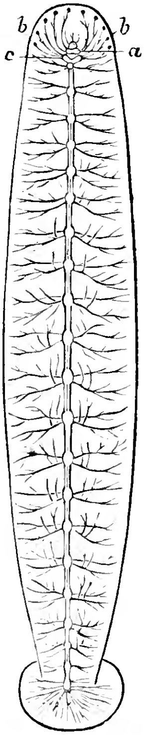

Fig. 2.—Nervous System of the Medicinal Leech.

on either side, whose branches are distributed to the muscles and parietes of adjacent segments.

In this animal also a simple filament is given off from the posterior part of the supra-œsophageal ganglion, and is distributed along the dorsal aspect of the alimentary canal. It foreshadows an important system of nerves corresponding partly with that of the "sympathetic," and partly with the pneumogastric (or lung and stomach) nerves in higher animals. This system is known among invertebrates as the "stomato-gastric system." In other members of the invertebrate series it frequently takes its origin from the commissures connecting the upper and lower ganglia, rather than from the upper ganglion itself. The more complicated stomato-gastric system of the earthworm has an origin of this kind.

The kind of nervous system which pertains to the earthworm and to the leech exists, with only comparatively trivial variations, throughout the whole sub-kingdom *Vermes.*

The next sub-kingdom—the *Arthropoda*—comprises centipedes, crabs, spiders, and insects. They are all characterized by the possession of hollow and jointed organs of locomotion, containing distinct muscles, these appendages being represented among *Vermes* only by lateral setæ or bristles of different kinds. The lowest types of these various classes possess a nervous system closely analogous to that existing among the various kinds of worms. In the more complex types of crabs, spiders, and insects, however, we meet with a great increase in the complexity of animal organization, and this increase of complexity is shared in by the nervous system. Among insects, for instance, the respiratory organs assume a marvelous degree of elaboration, and the development of this system, together with a correlated development of their nervous and muscular systems, contributes greatly to the enormous powers of locomotion for which these denizens of the air are remarkable. The acuteness and structural elaboration of their sense-organs is almost sure to be greatly increased in such active creatures; and, looking to the nature of the intelligence in these lower animals, there is thus afforded an increasing stimulus to brain-development and slightly higher brain-functions.

Among the lower centipedes, such as *Iulus* and *Geophilus*, in which the limbs, though very numerous, are feeble and ill-developed, the nervous system exhibits only a slight advance over the forms which it presents among the higher *Annelida* (Fig. 3). But in the more powerful predatory forms, of which the common centipede may be taken as a type, a distinct advance is met with. This carnivorous animal has a smaller number of well-developed limbs, and its nervous system closely resembles that found among caterpillars or the larvæ of higher insects.

The supra-œsophageal ganglia receive nerves from the two pairs of antennæ, and from the groups of ocelli on each side of the head, and they are connected by œsophageal cords with a bilobed infra-œsophageal ganglion, which distributes nerves to the jaws and other parts about the mouth. This bilobed infra-œsophageal ganglion is the first and largest of a series of ventral ganglia, numbering twenty-two in all, which are connected together by a double ventral cord. Every ganglion sends off nerves on each side to a pair of limbs.

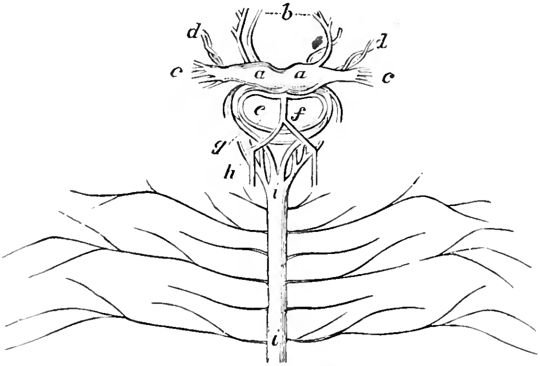

Fig. 3.—Brain and Adjacent Parts of Nervous System of Iulus.

From the posterior part of the brain, or from the œsophageal cords, the stomato-gastric nerves are given off, and distribute themselves over the alimentary canal in the usual manner.

Organs of vision become much more elaborate in crabs, spiders, and insects, than among worms or centipedes. And, while organs of touch and taste are further perfected in these higher arthropods, two new sensory endowments also become manifest. These organisms, or at least all the higher forms of them, are capable of being impressed by and of discriminating the different odors of some substances anterior to the contact of such substances with their gustatory surfaces. This new power aids them in their search for or recognition of food. Such organisms are, in addition, capable of appreciating those vibrations of the medium they inhabit, which induce in us impressions recognized as sounds or noises. In other words, they acquire a rudimentary power of hearing.

These additional sensory endowments are of high importance to all organisms, but more especially to those possessing active powers of locomotion—serving, as they do on the one hand, to help to bring their possessors into relation with food, and, on the other, to warn them of the approach of enemies, of friends, or of sexual mates.

Among *Crustacea* great differences are met with in the degree of concentration of the nervous system, the variations being in the main dependent upon differences of external form in the respective members of the class. In some of the lower terms of the series allied to wood-lice (such as talitrus and oniscus), in which the body is elongated and composed of many almost similar segments, the nervous system is not very different from that of the more highly-organized worms.

In slightly higher forms of *Crustacea*, however, the two divisions of the originally double ventral cord approximate and become fused together, while, at the same time, the equality of its ganglia diminishes. Thus, in such forms as the lobster and the crayfish, the ganglia of the thorax which supply nerves to the limbs are distinctly larger than those of the abdominal segments, though these are also of good size, since the tail-segments are actively called into play during locomotion.

In the prawn a further development and concentration of the nervous system is seen. The thoracic ganglia are fused into a single elliptical mass, though those of the abdominal segments still remain separate.

But in the ordinary edible crab and its allies (Fig. 4), a still more remarkable concentration of the nervous system is met with. All the thoracic and all the abdominal ganglia are here fused into one large perforated mass of nervous matter (*c*), situated near the middle of the ventral region of the body.[1] From this large compound ganglionic mass nerves are given off to the limbs, to the abortive tail, and to other parts.

The brain of the crab (*a*) is represented by a rather small bilobed ganglion. It receives nerves from the pedunculated compound eyes, from the two pairs of antennæ, and from the palpi-bearing mandibles. The posterior antennæ (or antennules, as they are sometimes termed) contain in their basal joint a body which is supposed to represent an olfactory organ, though others have regarded it (on very insufficient grounds) as an organ of hearing. The rather small bilobed brain is, indeed, regarded by many naturalists as essentially composed of three pairs of ganglia, completely fused into one another, but in relation with the three pairs of sensory organs—the eyes, the tactile antennæ, and the supposed olfactory antennules. It is connected, by means of a long cord (*b*, *b*), on each side of the œsophagus, with the anterior extremity of the great ventral ganglion. These cords are long because of the absence of any separate sub-œsophageal ganglia, and because of the comparative distance of the great ventral nervous mass into the composition of which these ganglia enter. The great length of the œsophageal cords is one of the most notable characteristics of the nervous system of the higher *Crustacea*.

The "stomato-gastric" system of *Crustacea* is closely similar to that which exists in centipedes. One part of it is given off from the œsophageal cord on each side, while another median branch proceeds from the posterior part of the united cephalic ganglia, as in *Iulus* (Fig. 3, *f*).

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[1] An artery passes through the perforation in this ganglion.

Among *Arachnida* forms of the nervous system exist which agree in many respects with those belonging to members of the class last described—these resemblances being in the main associated with certain general similarities of external form or configuration of body. Thus in scorpions the arrangement of the nervous system is not very dissimilar from that belonging to the prawn and its allies, since the thoracic ganglia have coalesced with one another and with the anterior abdominal ganglia, so as to form a large stellate nervous mass, which supplies the limbs and the anterior part of the abdomen. The ventral cord throughout the remainder of the abdomen and its caudal prolongation is marked at intervals by a series of small ganglionic swellings.

In spiders proper the nervous system attains its maximum of concentration. In addition to the abdominal and thoracic ganglia having all fused into one another and with the sub-œsophageal ganglion, we find the large mass thus composed (Fig. 5, *s*) brought into extremely close relation with the cerebral ganglia or brain (*c*). They are connected by means of two stout commissures, one on each side of the very narrow œsophagus, whose small size is attributable to the suctorial habits of these carnivorous and predatory creatures. The captured fly is not eaten, its juices are sucked by the fierce spider by whom its life has been taken.

Fig. 4.—Nervous System of a Crab (*Palinurus*).

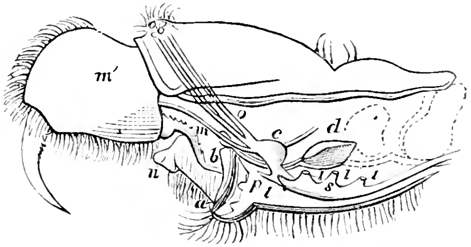

Fig. 5.—Head and Nervous System of a Spider (*Mygale*).

The bilobed brain of the spider receives nerves on each side (*o*), corresponding in number with the ocelli which the animal may possess. It also receives two large nerves (*m*) from the so-called mandibles, which are organs presumably developed from modified antennæ. These large nerves probably contain outgoing as well as ingoing fibres.

The sub-œsophageal ganglia correspond in the main, as we have already stated, with the medulla oblongata of vertebrate animals, and their fusion with the thoracic ganglia in the *Arachnida*, as well as in the *Crustacea* and *Myriapoda*, confirms the view held by some anatomists, that the medulla should be regarded as a prolongation of the spinal cord, rather than as an integral part of the brain.

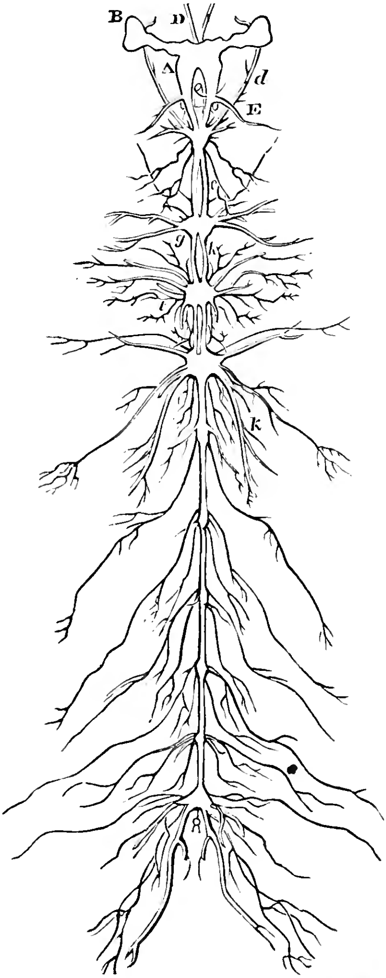

FIG. 6.—NERVOUS SYSTEM OF AN INSECT (*Acrida viridissima*).

The nervous system of insects varies not only among different classes and orders, but even in the same individual, in different stages of its development. The larva, or caterpillar, of a butterfly, for instance, presents a nervous system not very different from that met with in the centipede; while in the imago stage, or perfected insect, the same system has undergone some remarkable changes, leading to increased size of the cerebral ganglia, and also to further development of some of the ganglia pertaining to the ventral cord, with concentration or even suppression of others.

In such insects as butterflies, bees, and dragon-flies, in which the visual organs are enormously developed, and in which the power of vigorous and sustained flight is correspondingly increased, the nervous system attains its maximum of development among the *Arthropoda.* The brain of these creatures differs from that existing in all other members of the class by reason of the great development of those portions of it in relation with the visual organs. A ganglionic swelling is frequently found where the nerve joins the brain (Fig. 6, *B*,) and in some insects there are also small ganglionic swellings at the corresponding parts of the antennal nerves.

As in spiders, the œsophageal ring is very narrow, owing to the greatly-diminished size of the œsophagus in the imago forms of higher insects. The double upper or cerebral ganglion is, however, connected in all insects with a separate sub-œsophageal ganglion, from which nerves are given off to the mandibles, the maxillæ, and the labium, though in spiders, crustaceans, and myriapods, as I have before stated, this part has no existence separate from the thoracic ganglia.

In insects the three thoracic ganglia also often preserve a separate existence (Fig. 6), though in such higher types as I have named above these ganglia are more frequently fused into a single, lobed mass. The eight abdominal ganglia, which are always much smaller than the thoracic, continue to have a separate existence among some of the less developed types of insects, though it is more frequent for some, or even all, of them to disappear.

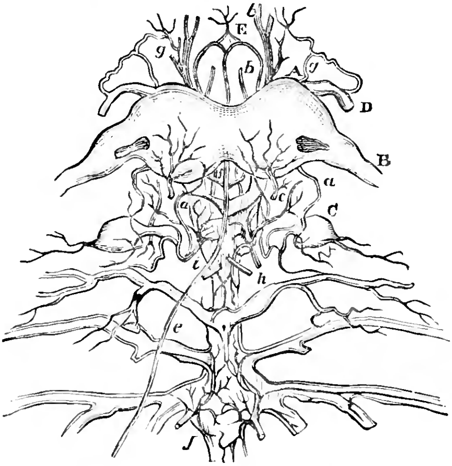

Fig. 7.—Brain and Adjacent Parts of Nervous System of the Privet Moth in the Pupa State.

The stomato-gastric system also attains considerable complexity in these animals. It is often connected anteriorly with a median frontal ganglion (Fig. 7, *E*), lying anterior to and below the brain, which supplies branches to the mouth and adjacent parts. This oral or frontal ganglion, besides being connected with the brain, also gives origin to a median recurrent nerve (*e*). This nerve is connected with other branches, proceeding from one or two pairs of lateral ganglia (*c*), near to, and taking origin from, the œsophageal cords. The system of nerves thus derived furnishes branches to the stomach, the intestines, and other viscera. In addition, we meet in insects with another well-developed set of visceral nerves, taking origin from a chain of minute ganglia, which lie upon and are connected with the large ventral ganglionated cord. These nerves are distributed to the extensive and greatly multiplied air-tubes, or respiratory organs. They are known to anatomists as "nervi transversi," and are much more developed in insects than are its representatives among any other class of arthropods.

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# MODERN SCIENTIFIC GEOGRAPHY.[1]

### By Dr. HERMANN J. KLEIN.

AMONG the various branches of natural science which have in recent times attained a high development, geography holds a prominent rank. By this, however, we must understand, not so much that vast regions of previously unexplored country have been made known to the educated world; that rivers, seas, and mountains, have been discovered, and the courses of known streams more accurately defined in maps; but rather that geotectonic[2] data, of which a rich store has been collected, have been studied from broad and general points of view, and the individual phenomena ranged in the order of cause and effect. In earlier times geography was simply a catalogue of facts, and the earth's surface an ultimate datum; but nowadays we are beginning to regard the superficies of our planet as a *result*, to investigate the relations between its separate parts, and to note the changes which occur in it. In the words of Karl Ritter: "Scientific geography by no means regards our planet as a lifeless, dead aggregate of an unorganized nature, or, as Herodotus expresses it, a disk turned on a lathe; but as a truly and specially organized body in steady process of development, bearing within itself the life-germs of further evolution. Herein consists its unity; and it is in virtue of this, its living principle, that it is a whole, lending itself to an orderly presentation and development of its great system. Furthermore, it is this which makes of it a science instructive to the human mind—an indispensa-

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[1] Translated from the German by J. Fitzgerald, A. M.

[2] Relating to the earth's structure.

ble portion of the system of the sciences." True, even in this broad conception, Ritter conveys no adequate idea of what scientific geography is. His illustrious labors were restricted to a narrower field, and we may say that he worked only upon a part of the foundations of the proud edifice which future ages will behold. Still, so far are we from wishing to discredit the important services rendered by this great geographer that we are free to confess that he achieved all that

Map of the Mediterranean Sea, showing the Relative Depths.

was possible in his day. Scientific geography is dependent upon a number of other sciences, and its progress is conditioned upon the development of these. No other science is so ill adapted as geography to advance independently and without external aid. When the astronomer aims at new applications of the theory of disturbance, or when the physicist studies the phenomena of polarization; when the chemist undertakes to break up combinations of elements, or the geologist investigates the relations subsisting between different strata, each of these investigators labors in his own province, almost entirely without reference to the progress made in other departments of science. But when, on the contrary, a traveler, like the enterprising Lieutenant Cameron, traverses broad continental regions over unexplored paths, the gain to scientific geography from such undertakings in great measure depends upon the development of astronomy, meteorology, geology, etc., inasmuch as it is by the aid of these sciences that we can discuss the observations that have been made, and turn them to account for ulterior conclusions. Then, too, we must not overlook those sciences which have to do with organic Nature and which consider from higher points of view the distribution of living beings. Bearing all this in mind, we can readily perceive how intimate is the connection between geography and all the natural sciences. Hence it is that in earlier times the idea of scientific geography could hardly be entertained. At first geography offered little besides an imperfectly-arranged mass of descriptions of strange lands and curious things; next it gradually invaded the domain of statistical facts; then the relations of the history of man to the earth's configuration were recognized and elucidated; at last came scientific geography, which investigates the relations between the structure of the earth and the sum of all terrestrial phenomena, both organic and inorganic. The following instance will show the distinction between ordinary (descriptive) geography and scientific geography.

No inconsiderable part of the surface of *terra firma* consists of deserts, those vast, dry, and in part sandy regions, the type of which is the Sahara. The old descriptive geography gives the geographical situation of these wastes, their superficial extent, the number and site of their oases, the names of the mountain-regions which traverse them, and perhaps a few observations after the manner of anecdotes upon the intense heat which prevails in such regions, and the perils of a journey through the desert.

Scientific geography, on the other hand, regards these deserts as an integral part of the terrestrial organism, and shows how their occurrence is not accidental, but a necessary result of the past and present distribution of land and water, and of the position of the zone of calms. It exhibits to us the process of forming deserts still active, inasmuch as there exist centres of sand-radiation. It solves for us the enigma of the formation of springs in the oases, inasmuch as it rejects as unverified the asserted absolute rainlessness of the deserts, and in the precipitated meteoric water finds a sufficient supply for the wells of the low-lying oases. With the aid of meteorology it shows how one continent tends to reduce another to the condition of a desert; and, taking man into the sphere of its observations, it discusses the influence of the soil and the configuration of a region upon the course of culture-development therein, and even upon the development of peculiarities of speech. Scientific geography in this way vivifies the dead superficies of our planet, and gives to the conventional lines of a map the power of speaking a language that is understood by the educated mind.

The endeavor to meet the requirements of a higher geography is also to be seen in the better style of our modern maps. Thus, whereas in former times the seas were represented by blank spaces surrounding the land, now we have the results of soundings carefully represented, and the lines of equal depths, as they are more or less parallel to the present contours of the coast, supply to the geographer valuable data with respect to the formation of the land itself. On looking at the sketch of the Mediterranean Sea, in which various depths from fifty to five hundred fathoms are represented, the reader will perceive far more clearly than he could from the mere contour of the coasts that, not taking the Black Sea into account, the Mediterranean Sea proper consists of two great basins, viz., a western basin, extending from Gibraltar to Cape Bon and the southwestern extremity of Sicily, and an eastern basin extending thence to the coast of Syria. The shallow depth between Africa and Sicily, and especially the track of the hundred-fathom line, shown in our map by a dotted curve, prove that, at a time not very remote geologically, Africa and Europe were much nearer to one another than they are now, and that in the still remoter past the two continents were connected at this point. In all probability this union existed at a period when as yet the present southern shore of the eastern Mediterranean basin had not been upheaved, and the sea covered a portion of what is now the Sahara. French investigators have supposed that the most recent retreat of the sea was from the Syrtis Minor; nay, that even in historic times the great Algerian Chotts were directly connected with the Mediterranean as an arm of that sea. But this hypothesis is negatived by G. Stache's discovery of a stratum characterized by land and fresh-water shells, at the base of the Quaternary formations which constitute the coast of the Gulf of Gabes.

If we take up a geological chart, e. g., the beautiful "General Map of the Sedimentary Formations of Europe," by H. Habenicht, we find nothing that contradicts these conclusions. Thus the Eocene formations, which are widely diffused over the northern extremity of Africa, and especially in Tunis, occur again in the island of Sicily, while the southern and the southwestern portion of that island show the most recent Tertiary strata. These same strata form the coast of Syrtis Major, where yet the Mediterranean extends farthest southward, and where probably was situated the last channel through which water was supplied to the sea that once covered a portion of the Sahara. That here gradual upheavals of the land have taken place, each upheaval succeeded by a protracted season of repose, is shown by the terraces, the origin of which is so well known to the geologist. Gerhard Rohlfs found these terraces as he ascended the rising ground back of Tolmita, the ancient Ptolemais. He observes that these terraces are separated from one another by levels several miles in width.[1]

But if, turning aside from these geological considerations, we again glance at our map of relative depths, we almost everywhere find that a flat coast accompanies a shallow sea; while, on the other hand, a mountainous coast implies a sudden and precipitous inclination of the neighboring sea-bottom. This would more plainly appear if our map were on a larger scale, and had a greater number of depth-curves for the purpose of comparison. This fact might be accounted for by supposing that the comparatively sudden upheaval of the coast-hills was connected with a considerable depression of the neighboring sea-bottom, while the slow and periodic sinking of the flatter portions gave rise to submarine terraces. But, aside from this hypothesis, the representation of graduated submarine depths has a significance not to be misunderstood in geological, zoölogical, and botanical investigations.

Turning now from the sea to the land, we find in our best modern maps a number of figures indicating, as accurately as possible, the elevations; nay, even the attempt has been made, in the magnificent atlas of Switzerland, to show the elevations by means of equidistant curves. The Lehmann method of representing the surface of a country with equidistant level-lines would be, in many respects, of the highest service for the study of the earth's surface, but as yet it can be practically employed only in individual cases, partly from the want of materials, partly also on account of technical difficulties.

Cartography is a powerful aid to scientific geography, inasmuch as it arranges in true projection a great mass of heterogeneous materials, bringing it before the eye within small space, and thus making apparent relations which else could hardly be noticed. As for political geography, viz., the description of the various empires of the world, their area, provinces, population, etc., this we would regard rather as a branch of statistics than of geography proper.—*Gaea.*

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[1] "Von Tripolis nach Alexandrien," 1. Bd., S. 169.

# PREDATORY AND INDUSTRIAL SOCIETIES.[1]

By HERBERT SPENCER.

A GLANCE at the respective antecedents of individual organisms and social organisms shows why the last admit of no such definite classification as the first. Through a thousand generations a species of plant or animal leads substantially the same kind of life; and its successive members inherit the acquired adaptations. When changed conditions cause divergences of forms once alike, the accumulating differences arising in descendants only superficially disguise the original identity—do not prevent the grouping of the several species into a genus; nor do wider divergences that began earlier prevent the grouping of genera into orders and orders into classes. It is otherwise with societies. Hordes of primitive men, dividing and subdividing, do, indeed, show us successions of small social aggregates leading like lives, inheriting such low structures as had resulted, and repeating those structures. But higher social aggregates propagate their respective types in much less decided ways. Though colonies tend to grow like their parents, yet the parent societies are so comparatively plastic, and the influences of new habitats on the derived societies are so great, that divergences of structure are inevitable. In the absence of definite organizations, established during the similar lives of many societies descending one from another, there cannot be the precise distinctions implied by complete classification.

Two cardinal kinds of differences there are, however, of which we may avail ourselves for grouping societies in a natural manner. Primarily we may arrange them, according to their degrees of composition, as simple, compound, doubly-compound, trebly-compound; and, secondarily, though in a less specific way, we may divide them into the predominantly predatory and the predominantly industrial—those in which the organization for offense and defense is most largely developed and those in which the sustaining organization is most largely developed.

We have seen that social evolution begins with small, simple aggregates; that it progresses by the clustering of these into larger aggregates; and that, after consolidating, such clusters are united with others like themselves into still larger aggregates. Our classification, then, must begin with societies of the first or simplest order.

We cannot in all cases say with precision what constitutes a simple society; for, in common with products of evolution generally, societies present transitional stages which negative sharp divisions. As the multiplying members of a group spread and diverge gradually, it

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[1] Abridged from advance-sheets of the "Principles of Sociology," Part II., "The Induction of Sociology," Chapter X., "Social Types and Constitutions."

is not always easy to decide when the groups into which they fall become distinct. Here the descendants of common ancestors, inhabiting a barren region, have to divide while yet the constituent families are near akin; and there, in a more fertile region, the group may hold together until clusters of families remotely akin are formed—clusters which, diffusing slowly, are held by a common bond that slowly weakens. By-and-by comes the complication arising from the presence of slaves not of the same ancestry, or of an ancestry but distantly allied; and these, though they may not be political units, must be recognized as units sociologically considered. Then there is the kindred complication arising where an invading tribe becomes a dominant class. Our only course is to regard as a simple society one which forms a single working whole, unsubjected to any other, and of which the parts coöperate, with or without a regulating centre, for certain public ends. Here is a table, presenting, with as much definiteness as may be, the chief divisions and subdivisions of such simple societies.[1] . . .

We pass now to the classification based on unlikenesses between the kinds of social activity which predominate, and on the resulting unlikenesses of organization. The two social types thus essentially contrasted are the predatory and the industrial.

It is doubtless true that no definite separation of these can be made. Excluding a few simple groups, such as the Esquimaux, inhabiting places where they are safe from invasion, all societies, simple and compound, are occasionally or habitually in antagonism with other societies; and, as we have seen, tend to evolve structures for carrying on offensive and defensive actions. At the same time sustentation is necessary, and there is always an organization, slight or decided, for achieving it. But while the two systems in social organisms, as in individual organisms, coexist in all but the rudimentary forms, they vary immensely in the ratios they bear to one another. In some cases the structures carrying on external actions are largely developed; the sustaining system exists solely for their benefit, and the activities are militant. In other cases there is predominance of the structures carrying on sustentation; offensive and defensive structures are maintained only to protect them; and the activities are industrial. At the one extreme we have those warlike tribes which, subsisting mainly by the chase, make the appliances for dealing with enemies serve also for procuring food, and have sustaining systems represented only by their women, who are their slave-classes; while at the other extreme we have the type, as yet only partially evolved, in which the agricultural, manufacturing, and commercial

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[1] Three elaborate tables are here given in the text of Spencer's work, classifying the social aggregates of mankind into "Simple Societies," "Compound Societies," and "Doubly-Compound Societies." We are compelled to omit them and the accompanying text for want of space.

organizations form the chief part of the society, and, in the absence of external enemies, the appliances for offense and defense are either rudimentary or absent. Transitional as are nearly all the societies we have to study, we may yet clearly distinguish the constitutional traits of these opposite types, characterized by predominance of the outer and inner systems respectively.

Having glanced at the two thus placed in contrast, it will be most convenient to contemplate each by itself.

As before pointed out, the militant type is one in which the army is the nation mobilized, while the nation is the quiescent army, and which, therefore, acquires a structure common to army and nation. We shall most clearly understand its nature by observing in detail this parallelism between the military organization and the social organization at large.

Already we have had ample proof that centralized control is the primary trait acquired by every body of fighting-men, be it horde of savages, group of brigands, or mass of soldiers. And this centralized control, necessitated during war, characterizes the government during peace. Among the uncivilized, there is a marked tendency for the military chief to become also the political head (the medicine-man being his only competitor); and in a conquering race of savages his political headship becomes fixed. Among semi-civilized, the conquering commander and the despotic king are the same; and they remain the same among the civilized down to late times. The connection is well shown where, in the same race, we find a contrast in the habitual activities and in the forms of government. Thus the powers of the patriarchal chiefs of Kaffre tribes are not great; but the Zulus, who have become a conquering division of the Kaffres, are under an absolute monarch. Of advanced savages, the Feejeeans may be named as well showing this relation between habitual war and despotic rule; the persons and property of subjects are entirely at the king's or chief's disposal. We have seen that it is the same in the warlike African states, Dahomey and Ashantee. The ancient Mexicans, again, whose highest profession was that of arms, and whose eligible prince became king only by feats in war, had an autocratic government, which, according to Clavigero, became more stringent as the territory was enlarged by conquest. Similarly, the unmitigated despotism under which the Peruvians lived had been established during the spread of the Inca conquests. And that race is not the cause, we are shown by this recurrence in ancient America of a relation so familiar in ancient states of the Old World.

The absoluteness of a commander-in-chief goes along with absolute control exercised by his generals over their subordinates, and by their subordinates over the men under them. All are slaves to those above, and despots to those below. This structure repeats itself in the accompanying social arrangements. There are precise gradations of rank in the community, and complete submission of each rank to the ranks above it. We see this in the society already instanced, as showing, among advanced savages, the development of the militant type. In Feejee six classes are enumerated, from king down to slaves, as sharply marked off. Similarly in Madagascar, where despotism has been in late times established by war, there are several grades and castes. Among the Dahomans, given in so great a degree to bloodshed of all kinds, "the army, or, what is nearly synonymous, the nation," says Burton, "is divided, both male and female, into two wings;" and then, of the various ranks enumerated, all are characterized as legally slaves of the king. In Ashantee, too, where his officers are required to die when the king dies, we have a kindred condition. Of old, among the aggressive Persians, grades were strongly marked. So was it in warlike ancient Mexico. Besides three classes of nobility, and besides the mercantile classes, there were three agricultural classes down to the serfs—all in precise subordination. In Peru, also, below the Inca there were grades of nobility—lords over lords. Moreover, according to Garcilasso, in each town the inhabitants were registered in decades under a decurion, five of these under a superior, two such under a higher one, five of these centurions under a head, two of these under one who thus ruled a thousand men, and for every ten thousand there was a governor of Inca race; the political rule being thus completely regimental. Till lately, another illustration was furnished by Japan. That there were kindred, if less elaborate, structures in ancient militant states of the Old World, scarcely needs saying; and that like structures were repeated in mediæval times, when a large nation, like France, had under the monarch several grades of feudal lords, vassals to those above, and suzerains to those below, with serfs under the lowest, again shows us that everywhere the militant type has sharply-marked social gradations, as it has sharply-marked military gradations.

Corresponding to this natural government, there is a like form of supernatural government. I do not mean merely that, in the ideal other-worlds of militant societies, the ranks and powers are conceived as like those of the real world around, though this also is to be noted; but I refer to the militant character of the religion. Ever in antagonism with other societies, the life is a life of enmity, and the religion a religon of enmity. The duty of blood-revenge, most sacred of all with the savage, continues to be the dominant duty as the militant type of society evolves. The chief, balked of his vengeance, dies enjoining his successors to avenge him; his ghost is propitiated by fulfillment of his commands; the slaying of his enemies becomes the highest action; trophies are brought to his grave in token of fulfillment; and, as tradition grows, he becomes the god worshiped with bloody sacrifices. Everywhere we find evidence. The Feejeeans offer the bodies of their victims killed in war to the gods before cooking them. In Dahomey, where the militant type is so far developed that women are warriors, men are almost daily sacrificed by the monarch to please his dead father; and the ghosts of old kings are invoked for aid in war by blood sprinkled on their tombs. The war-god of the Mexicans (originally a conqueror), the most revered of their gods, had his idol fed with human flesh; wars being undertaken to supply him with victims. And similarly in Peru, where there were habitual human sacrifices, men taken captive were immolated to the father of the Incas, the sun. How militant societies of old in the East similarly evolved deities, who were similarly propitiated by bloody rites, needs merely indicating. Habitually their mythologies represent gods as conquerors; habitually their gods are named "the strong one," "the destroyer," "the avenger," "god of battles," "lord of hosts," "man of war," and so forth. As we read in Assyrian inscriptions, wars were commenced by their alleged will; and, as we read elsewhere, peoples were massacred wholesale in professed obedience to them. How its theological government, like its political government, is essentially military, we see even in late and qualified forms of the predatory type; for, down to the present time, absolute subordination, like that of soldier to commander, is the supreme virtue, and disobedience the crime for which eternal torture is threatened.

Similarly with the accompanying ecclesiastical organization. Very generally, where the militant type is highly developed, the political head and ecclesiastical head are identical—the king, chief descendant of his ancestor, who has become a god, is also chief propitiator of him. It was so in ancient Peru; and in Tezcuco and Tlacopan (Mexico) the high-priest was the king's second son. The Egyptian wall-paintings show us kings performing sacrifices; as do also the Assyrian. Babylonian records harmonize with Hebrew traditions in telling us of priest-kings. In Lydia it was the same; Crœsus was king and priest. In Sparta, too, the kings, while military chiefs, were also high-priests; and a trace of the like original relation existed in Rome. A system of subordination, essentially akin to the military, has habitually characterized the accompanying priesthoods. The Feejeeans have an hereditary priesthood, forming a hierarchy. In Tahiti, where the high-priest was royal, there were grades of hereditary priests belonging to each social rank. In ancient Mexico the priesthoods of different gods had different ranks, and there were three ranks within each priesthood; and in ancient Peru, besides the royal chief priest, there were priests of the conquering race set over various classes of inferior priests. A like type of structure, with subjection of rank to rank, has characterized priesthoods in the ancient and modern belligerent societies of the Old World. The like mode of government is traceable throughout the sustaining organization also, so long as the social type remains predominantly militant. Beginning with simple societies, in which the slave-class furnishes the warrior-class with necessaries of life, we have already seen that, during the subsequent stages of evolution, the industrial part of the society continues to be essentially a permanent commissariat, existing solely to supply the needs of the governmental-military structures, and having left over for itself only enough for bare maintenance. Hence, the development of political regulation over its activities has been in fact the extension throughout it of that military rule which, as a permanent commissariat, it naturally had. An extreme instance is furnished us by the ancient Peruvians, whose political and industrial governments were identical—whose kinds and quantities of labor, for every class in every locality, were prescribed by laws enforced by state officers—who had work legally dictated even for their young children, their blind, and their lame, and who were publicly chastised for idleness; regimental discipline being applied to industry just as our modern advocate of strong government would have it now. The late Japanese system, completely military in origin and nature, similarly permeated industry; great and small things—houses, ships, down even to mats—were prescribed in their structures. In the warlike monarchy of Madagascar, the artisan classes are all in the employ of government, and no man can change his occupation or locality, under pain of death. Without multiplication of cases, these typical ones, reminding the reader of the extent to which, even in modern fighting states, industrial activities are officially regulated, will sufficiently show the principle.

Not industry only, but life at large, is, in militant societies, subject to kindred discipline. Before its recent collapse, the government of Japan enforced sumptuary laws on each class, mercantile and other, up to the provincial governors, who must rise, dine, go out, give audience, and retire to rest at prescribed hours; and the native literature specifies regulations of a scarcely credible minuteness. In ancient Peru, officers "minutely inspected the houses, to see that the man, as well as his wife, kept the household in proper order, and preserved a due state of discipline among their children;" and householders were rewarded or chastised accordingly. Among the Egyptians each person had, at fixed intervals, to report to a local officer his name, abode, and mode of living. Sparta, too, yields an example of a society specially organized for offense and defense, in which the private conduct of citizens, in all its details, was under public control enforced by spies and censors. Though regulations so stringent have not characterized the militant type in more recent ages, yet we need but recall the laws regulating food and dress, the restraints on locomotion, the prohibitions of some games and dictation of others, to indicate the parallelism of principle. Even now, where the military organization has been kept in vigor by military activities, as in France, we are shown, by the peremptory control of journals and suppression of meetings, by the regimental uniformity of education, by the official administration of the fine arts, the way in which its characteristic regulating system ramifies everywhere.

And then, lastly, is to be noted the theory concerning the relation between the state and the individual, with its accompanying sentiment. This structure, which adapts a society for combined action against other societies, is associated with the belief that its members exist for the benefit of the whole, and not the whole for the benefit of its members. As in an army the liberty of the soldier is denied, and only his duty as a member of the mass insisted on; as in a permanently encamped army, like the Spartan nation, the laws recognized no personal interests, but patriotic ones only; so in the militant type throughout the claims of the unit are nothing, and the claims of the aggregate everything. Absolute subjection to authority is the supreme virtue, and resistance to it a crime. Other offenses may be condoned, but disloyalty is an unpardonable offense. If we take the sentiments of the sanguinary Feejeeans, among whom loyalty is so intense that a man stands unbound to be knocked on the head, himself saying that what the king wills must be done; or those of the Dahomans, among whom the highest officials are the king's slaves, and on his decease his women sacrifice one another that they may all follow him; or those of the ancient Peruvians, among whom with a dead Inca, or great *curaca*, were buried alive his favorite attendants and wives that they might go to serve him in the other world; or those of the ancient Persians, among whom a father, seeing his innocent son shot by the king in pure wantonness, "felicitated" the king "on the excellence of his archery," and among whom bastinadoed subjects "declared themselves delighted because his majesty had condescended to recollect them"—we are sufficiently shown that, in this social type, the sentiment which prompts the assertion of personal rights, in opposition to the ruling power, scarcely exists.

Thus the trait characterizing the militant structure throughout is that its units are coerced into their various combined actions. As the soldier's will is so suspended that he becomes in everything the agent of his officer's will, so is the will of the citizen in all transactions, private and public, overruled by that of the government. The coöperation by which the life of the militant society is maintained, is a *compulsory* coöperation. The social structure adapted for dealing with surrounding hostile societies is under a centralized regulating system, to which all the parts are completely subject; just as in the individual organism the outer organs are completely subject to the chief nervous centre.

The traits of the industrial type have to be generalized from inadequate and entangled data. Antagonism, more or less constant with other societies, having been almost everywhere and always the condition of each society, a social structure fitted for offense and defense exists in nearly all cases, and disguises the structure which social sustentation alone otherwise originates. Such conception as may be formed of it has to be formed from what we find in the few simple societies that have been habitually peaceful, and in the advanced compound societies which, though once habitually militant, have become gradually less so.

Already I have referred to the chiefless Arafuras, living in "peace and brotherly love with one another," of whom we are told that "they recognize the rights of property in the fullest sense of the word, without there being any authority among them than the decisions of their elders, according to the customs of their forefathers;" that is, there has grown up a recognition of mutual claims and personal rights, with voluntary submission to a tacitly-elected representative government, formed of the most experienced. Among the Todas, who "lead a peaceful, tranquil life," disputes are "settled either by arbitration" or by "a council of five." The amiable Bodo and Dhimals, said to be wholly unmilitary, display an essentially free social form. They have nothing but powerless head-men, and are without slaves or servants; but they give mutual assistance in clearing ground and house-building. There is voluntary exchange of services—giving of equivalents of labor. The Mishmis, again, described as quiet, inoffensive, not warlike, and only occasionally uniting in self-defense, have scarcely any political organization. Their village communities, under merely nominal chiefs, acknowledge no common chief of the tribe, and the rule is democratic. Crimes are judged by an assembly.

Naturally, few, if any, cases occur in which societies of this type have evolved into larger societies without passing into the predatory type; for, as we have seen, the consolidation of simple aggregates into a compound aggregate habitually results from war, defensive or offensive, which, if continued, evolves a centralized authority with its coercive institutions. The Pueblos, however, industrious and peaceful agriculturists, who, building their unique villages, or compound houses, containing 2,000 people, in such ways as to "wall out black barbarism," fight only when invaded, show us a democratic form of government. "The governor and his council are elected annually by the people." The case of Samoa, too, may be named as showing, to some extent, how, in one of these compound communities, where the warlike activity is now not considerable, decline in the rigidity of political control has gone along with some evolution of the industrial type. Chiefs and minor heads, partly hereditary and partly elective, are held responsible for the conduct of affairs; there are village parliaments and district parliaments. Along with this we find a considerably-developed sustaining organization separate from the political—masters, who have apprentices, employ journeymen, and pay wages; and, when payment for work is inadequate, there are even strikes, upheld by a tacit trades-unionism.

Passing to more evolved societies, it must be observed, first, that the distinctive traits of the industrial type do not become marked, even where the industrial activity is considerable, so long as the industrial government remains identified with the political. In Phœnicia, for example, "the foreign wholesale trade seems to have belonged mostly to the state, the kings, and the nobles. . . . Ezekiel describes the King of Tyrus as a prudent commercial prince, who finds out the precious metals in their hidden seats, enriches himself by getting them, and increases these riches by further traffic." Clearly, where the political and military heads have thus themselves become the heads of the industrial organization, the traits distinctive of it are prevented from showing themselves. Of ancient societies, to be named in connection with the relation between industrial activities and free institutions, Athens will be at once thought of; and, by contrast with other Greek states, it showed this relation as clearly as can be expected. Up to the time of Solon, all these communities were under either oligarchs or despots. The rest of them, in which war continued to be the honored occupation, while industry was despised, retained this political type; but in Athens, where industry was regarded with comparative respect, where it was encouraged by Solon, and where immigrant artisans found a home, there commenced an industrial organization, which, gradually growing, distinguished the Athenian society from adjacent societies, as it was distinguished from them by those democratic institutions that simultaneously developed.

Turning to later times, the relation between a social *régime* predominantly industrial and a less coercive form of rule, is shown us by the Hanse Towns, by the towns of the Low Countries, out of which the Dutch Republic rose, and in high degrees by ourselves, by the United States, and by our colonies. Along with wars less frequent, and these carried on at a distance; and along with an accompanying growth of agriculture, manufactures, and commerce, beyond that of Continental states more military in habit—there has gone in England a development of free institutions. As further implying that the two are related, as cause and consequence, there may be noted the fact that the regions whence changes toward greater political liberty have come are the leading industrial regions; and that rural districts, less characterized by constant trading transactions, have retained longer the earlier type, with its appropriate sentiments and ideas. In the form of ecclesiastical government we see parallel changes. Where the industrial activities and structures evolve, this branch of the regulating system, no longer, as in the predatory type, a rigid hierarchy, little by little loses strength, while there grows up one of a different kind; sentiments and institutions both relaxing. Right of private judgment in religious matters gradually establishes itself along with establishment of political rights. In place of a uniform belief imperatively enforced, there come multiform beliefs voluntarily accepted; and the ever-multiplying bodies espousing these beliefs, instead of being governed despotically, govern themselves after a manner more or less representative. Military conformity, coercively maintained, gives place to a varied non-conformity maintained by willing union.

The industrial organization itself, which thus, as it becomes predominant, affects all the rest, of course shows us in an especial degree this change of structure. From the primitive predatory condition, under which the master maintains slaves to work for him, there is a transition through stages of increasing freedom to a condition like our own, in which all who work and employ, buy and sell, are entirely independent; and in which there is an unchecked power of forming associations that rule themselves on democratic principles. Combinations of workmen, and counter-combinations of employers, no less than political societies and leagues for carrying on this or that agitation, show us the representative mode of government; which characterizes also every joint-stock company for mining, banking, railway-making, or other commercial enterprise. Further, we see that, as in the predatory type the military mode of regulation ramifies into all minor departments of social activity, so here does the industrial mode of regulation. Multitudinous objects are achieved by spontaneously-evolved combinations of citizens governed representatively. The tendency to this kind of organization is so ingrained that, for every proposed end, the proposed means is a society ruled by an elected committee headed by an elected chairman — philanthropic associations of multitudinous kinds, literary institutions, libraries, clubs, bodies for fostering the various sciences and arts, etc., etc.

Along with all which traits there go sentiments and ideas concerning the relation between the citizen and the state, opposite to those accompanying the predatory type. In place of the doctrine that the duty of obedience to the governing agent is unqualified, there arises the doctrine that the will of the citizens is supreme, and the governing agent exists merely to carry out their will. Thus subordinated in authority, the regulating power is also restricted in range. Instead of having an authority extending over actions of all kinds, it is shut out from large classes of actions. Its control over ways of living in respect to food, clothing, amusements, is repudiated; it is not allowed to dictate modes of production, nor to regulate trade. Nor is this all. It becomes a duty to resist irresponsible government, and also to resist the excesses of responsible government. There arises a tendency in minorities to disobey even the legislature deputed by the majority, when it interferes in certain ways; and their oppositions to laws they condemn as inequitable from time to time cause abolition of them. With which changes of political theory and accompanying sentiment is joined a belief, implied or avowed, that the combined actions of the social aggregate have for their end to maintain the conditions under which individual lives may be satisfactorily carried on; in place of the old belief that individual lives have for their end the maintenance of this aggregate's combined actions.

These pervading traits, in which the industrial type differs so widely from the predatory type, originate in those relations of individuals implied by industrial activities, which are wholly unlike those implied by predatory activities. All trading transactions, whether between masters and workmen, buyers and sellers of commodities, or professional men and those they aid, are effected by free exchange. For some benefit which A's occupation enables him to give, B willingly yields up an equivalent benefit; if not in the form of something he has produced, then in the form of money gained by his occupation. This relation, in which the mutual rendering of services is unforced and neither individual subordinated, becomes the predominant relation throughout society, in proportion as the industrial activities predominate. Daily determining the thoughts and sentiments, daily disciplining all in asserting their own claims, while forcing them to recognize the correlative claims of others, it produces social units whose mental structures and habits mould social arrangements into corresponding forms. There results this type characterized throughout by that same individual freedom which every commercial transaction implies. The coöperation by which the multiform activities of the societies are carried on, becomes a *voluntary* coöperation. And while the developed sustaining system, which gives to a social organism the industrial type, acquires for itself, like the developed sustaining system of an animal, a regulating apparatus of a diffused or uncentralized kind, it tends also to decentralize the primary regulating apparatus, by making it derive from more numerous classes its deputed powers.

Necessarily the essential traits of these two social types are in most cases obscured, both by the antecedents and by the coexisting circumstances. Every society has been, at each past period, and is at present, conditioned in a way more or less unlike the ways in which others have been and are conditioned. Hence, the production of structures, characterizing one or other of these opposed types, is, in every instance, furthered, or hindered, or modified, in a special manner. Observe the several kinds of causes.

There is, first, the deeply-organized character of the particular race, coming down from those prehistoric times during which the diffusion of mankind, and differentiation of the varieties of man, took place. Very difficult to change, this must in every case qualify differently the tendency toward assumption of either type.

There is, next, the effect due to the immediately preceding mode of life and social type. Nearly always the society we have to study contains decayed institutions and habits belonging to an ancestral society otherwise circumstanced; and these pervert, more or less, the effects of circumstances then existing.

Again, there are the peculiarities of the habitat in respect of contour, soil, climate, flora, fauna, severally affecting in one mode or other the activities, whether predatory or industrial; and severally hindering or aiding, in some special way, the development of either type.

Yet further, there are the complications caused by the particular organizations and practices of surrounding societies. For, supposing the amount of offensive or defensive action to be the same, the nature of it depends in each case on the nature of the antagonist action; and hence its reactive effects on structure vary with the character of the antagonist. Add to this that direct imitation of adjacent societies is a factor of some moment.

There remains to be named an element of complication more potent perhaps than any of these—one which of itself often goes far to determine the type as predatory, and which in every case profoundly modifies the social arrangements. I refer to the mixture of races, caused by conquest or otherwise. We may properly treat of it separately under the head of social constitution—not, of course, constitution politically understood, but constitution understood as referring to the relative homogeneity or heterogeneity of the units constituting the social aggregate.

Inevitably as the nature of the aggregate, partially determined by environing conditions, is in other respects determined by the natures of its units, where its units are of diverse natures, the degrees of contrast between the two or more kinds of them, and the degrees of union between them, must greatly affect the results. Are they of unallied races, or of races near akin? and do they remain separate, or do they mix?

If units of two kinds are joined in the same society, their respective tendencies to evolve structures more or less unlike in character must modify the product. And the special modification will in every case further or hinder the evolution of one or the other social type. Clearly, where it has happened that a conquering race, continuing to govern a subject race, has developed the predatory regulating system throughout the whole social structure, and for ages habituated its units to compulsory coöperation—where it has also happened that the correlative ecclesiastical system, with its appropriate cult, has given to absolute subordination the religious sanction—and especially where, as in China, each individual is moulded by the governing power and stamped with the appropriate ideas of duty which it is heresy to question, it becomes impossible for any considerable change to be wrought in the social structure by other influences. It is the law of all organization that as it becomes complete it becomes rigid. Only where incompleteness implies a remaining plasticity is it possible for the type to develop from the original predatory form to the form which industrial activity generates.

Especially where the two races, contrasted in their natures, do not mix, social coöperation implies a compulsory regulating system; the military form of structure, which the dominant impose, ramifies throughout. Ancient Peru furnished an extreme case; and the Ottoman Empire may be instanced. Social constitutions of this kind, in which aptitudes for forming unlike structures coexist, are manifestly in states of unstable equilibrium. Any considerable shock dissolves the organization; and, in the absence of unity of tendency, reëstablishment of it is difficult, if not impossible. In cases where the conquering and conquered, though widely unlike, intermarry extensively, a kindred effect is produced in another way. The conflicting tendencies toward different social types, instead of existing in separate individuals, now exist in the same individual. The half-caste, inheriting from one line of ancestry proclivities adapted to one set of institutions, and from the other line of ancestry proclivities adapted to another set of institutions, is not fitted for either. He is a unit whose nature has not been moulded by any social type, and therefore cannot, with others like himself, evolve any social type. Modern Mexico and the South American republics, with their perpetual revolutions, show us the result.

It is observable, too, that, where races of strongly-contrasted natures have mixed more or less, or, remaining but little mixed, occupy adjacent areas subject to the same government, the equilibrium maintained so long as that government keeps up the coercive form shows itself to be unstable when the coercion relaxes. Spain, with its diverse peoples, Basque, Celtic, Gothic, Moorish, Jewish, partially mingled and partially localized, shows us this result.

Small differences, however, seem advantageous. Sundry instances point to the conclusion that a society formed from nearly-allied peoples, of which the conquering eventually mingles with the conquered, is relatively well fitted for progress. From their fusion results a community which, determined in its leading traits by the character common to the two, is prevented by their differences of character from being determined in its minor traits—is left capable of taking on new arrangements determined by new influences: medium plasticity allows those changes of structure constituting advance in heterogeneity. One example is furnished us by the Hebrews, who, notwithstanding their boasted purity of blood, resulted from a mixing of many Semitic varieties in the country east of the Nile, and who, both in their wanderings and after the conquest of Palestine, went on amalgamating kindred tribes. Another is supplied by the Athenians, whose progress had for antecedent the mingling of numerous immigrants from other Greek states with the Greeks of the locality. The fusion by conquest of the Romans with other Aryan tribes, Sabini, Sabelli, and Samnites, preceded the first ascending stage of the Roman civilization. And our own country, peopled by different divisions of the Aryan race, and mainly by varieties of Scandinavians, again illustrates this effect produced by the mixture of units sufficiently alike to coöperate in the same social system, but sufficiently unlike to prevent that social system from becoming forthwith definite in structure.

Admitting that the evidence where so many causes are in operation cannot be satisfactorily disentangled, and claiming only probability for these inductions respecting social constitutions, it remains to point out their analogy to certain inductions respecting the constitutions of individual living things. Between organisms widely unlike in kind, no progeny can arise: the physiological units contributed by them respectively to form a fertilized germ cannot work together so as to produce a new organism. Evidently as, while multiplying, the two classes of units tend to build themselves into two different structures, their conflict prevents the formation of any structure. If the two organisms are less unlike in kind—belonging, say, to the same genus though to different species—the two structures which their two groups of physiological units tend to build up being tolerably similar, they can, and do, coöperate in making an organism that is intermediate. But this, though it will work, is imperfect in its latest-evolved parts: there results a mule incapable of propagating. If, instead of different species, remote varieties are united, the intermediate organism is not infertile; but many facts suggest the conclusion that infertility results in subsequent generations: the incongruous working of the united structures, though longer in showing itself, comes out ultimately. And then, finally, if, instead of remote varieties, varieties nearly allied are united, a permanently-fertile breed results; and, while the slight differences of the two kinds of physiological units are not such as to prevent harmonious coöperation, they are such as conduce to plasticity and unusually vigorous growth.

Here, then, seems a parallel to the conclusion indicated above, that hybrid societies are imperfectly organizable—cannot grow into forms completely stable; while societies that have been evolved from mixtures of nearly-allied varieties of man can assume stable structures, and have an advantageous modifiability.

We class societies, then, in two ways; both having to be kept in mind when interpreting social phenomena:

First, they have to be arranged in the order of their integration, as simple, compound, doubly-compound, trebly-compound. And, along with the increasing degrees of evolution implied by these ascending stages of composition, we have to recognize the increasing degrees of evolution implied by growing heterogeneity, general and local.

Much less definite is the division to be made among societies according as one or other of their great systems of organs is supreme.

Omitting those lowest types which show no differentiations at all, we have but few exceptions to the rule that each society has structures for carrying on conflict with other societies and structures for carrying on sustentation; and the ratios between these admitting of all gradations, it results that no specific classification can be based on their relative developments. Nevertheless, as the predatory type, characterized by predominance of the one, is framed on the principle of compulsory coöperation, while the industrial type, characterized by predominance of the other, is framed on the principle of voluntary coöperation, the two types, when severally evolved to their extreme forms, are diametrically opposed; and the contrasts between their traits are among the most important with which sociology has to deal.

Were this the fit place, some pages might be added respecting a possible future social type, differing as much from the industrial as this does from the predatory—a type which, having a sustaining system more fully developed than any we know at present, will use the products of industry neither for maintaining a predatory organization nor exclusively for material aggrandizement; but will devote them to the carrying on of higher activities. As the contrast between the predatory and the industrial types is indicated by inverting the belief that individuals exist for the benefit of the state into the belief that the state exists for the benefit of individuals, so the contrast between the industrial type and the type likely to be evolved from it is indicated by the inversion of the belief that life is for work into the belief that work is for life. But we are here concerned with inductions derived from societies that have been and are, and cannot enter upon speculations respecting societies that may be. Merely naming as a sign the multiplication of institutions and appliances for intellectual and æsthetic culture, and for kindred activities not of a directly life-sustaining kind, but of a kind having gratification for their immediate purpose, I can here say no more.

Returning from this parenthetical suggestion, there remains the remark that to the complications caused by the crossings of these two classifications have to be added the complications caused by the unions of races widely unlike or little unlike; which here mix not at all, there partially, and in other cases wholly. Respecting these kinds of constitutions, we have considerable warrant for concluding that the hybrid kind, essentially unstable, admits of being organized only on the principle of compulsory coöperation; since units much opposed in their natures cannot work together spontaneously. While, conversely, the kind characterized by likeness in its units is relatively stable; and under fit conditions may evolve into the industrial type, especially if the likeness is qualified by slight differences.

# ORGANIZED HOMESTEADS AND HOUSEHOLDS.[1]

By WILLIAM F. CHANNING, M. D.

THE problem of homes for the people is not a simple one. The question is not merely how to house single families at the least cost. No solution of the problem can be worse than the solitary farm-house in a thinly-settled country. The real question is, how to reconcile the autonomy of the individual and family with the economies and productive forces of modern society. The solitary farm-house is a pioneer in the wilderness, and good for that. But the first generation born in it, or as soon as civilization has spread far enough to take it in, fly from it as if it were a pest-house. In the older States our population is rushing into the towns, not because the earth has grown barren, or because our town-life is natural or beautiful, but because modern civilization attracts and marshals mankind to coöperative work, and the universal instinct revolts against anti-social methods and solutions. More farmers and farmers' wives, in proportion to the population, are insane, than any other industrial or professional class in America; and this, notwithstanding all the healthful influences of Nature in the country, and the miasm, filth, and imprisonment, of the towns.

The first step toward social order is to secure the independent existence of the individual or family in a home which, like the traditional English house, shall be a castle inviolable and safe from all intrusion. One of the chief conditions of such independence is that the home shall be *owned* by the individual or family, *not rented.* On this account it introduces the wildest confusion into the present discussion to compare the working-men's houses in Philadelphia, owned by themselves, with hired tenements. We are brought, however, at once to a legitimate though limited ground of preference for the Philadelphia plan of purchasing a homestead, over the common method of living in rented houses, or in hired rooms in a tenement-house.

But this is only half of the question. The wastefulness of building a separate house for each family, even with the cheapest appliances, and of carrying on the household afterward, *will be always sufficient to make the difference between comfort and pauperism for the masses.* In other words, which will bear repetition, the separate house does not, cannot avail itself of the social economies and productive forces which are the means of modern civilization. Two great departments of human industry, *Agriculture, already alluded to, and the Household, remain in the hand-loom state of development.*

What is needed in agriculture to charm the population back to

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[1] A paper read before the American Social Science Association at Philadelphia, June 1, 1876.

the fields, and to double the production of the soil, is to substitute suitable buildings at the centre of an agricultural township for unsuitable, straggling farm-houses and barns, and to replace solitary labor on farms by the modern method of organized industry, applied to the cultivation of a domain *large enough* to permit *selection of soils* and the use of *adequate machinery*. This question, "How can we keep the boys on the farm?" has just received a thoughtful answer from Colonel George E. Waring, in an "Ogden Farm-Paper," in the April number of the *American Agriculturist*.

What we need, in order to harmonize our household system with other branches of modern industry, is a *Federative Homestead*, *owned by those inhabiting it*, in which the great entries or halls may be considered as *streets under cover*, and the individual or family domiciles, *houses under a common roof*. For such buildings a new architecture and new machinery are needed. The Peabody tenement-houses in London, the family club-houses in England and on the Continent, the family hotels in this country, and the Familistère at Guise, though furnishing valuable architectural suggestions, have solved as yet but few of the problems of construction of the "People's Palace," as it has been called. Invention also has done comparatively little to furnish labor-saving machinery for agriculture and the household on account of the segregated and slovenly character of these industries.

The most obvious form of the People's Palace in the town is a hollow square, surrounded with streets, with inclosed and surrounding gardens—the space in the centre being large enough to give air and a pleasant outlook to the inner domiciles. To further this object, one side of the square might be left open, or devoted to work-rooms, only a single story in height. In the country the building might take the form of a cross, giving an open view on all sides with public rooms and halls, or a conservatory under glass (a winter garden) in the middle, and gardens surrounding.

The economies would increase, and also the independence of the occupants, with the increase of numbers within certain limits. While the edifice might be of equal size for rich or poor, the separate domiciles would naturally be smaller and more numerous where the means of the proprietors were less. In the same building the various domiciles would differ in value according to situation and size, and thus would suit persons of different means. Not less than one hundred nor more than four hundred families may be assumed for illustration as probable limits of number.

A building of architectural beauty, favorably situated in country or town, to contain one hundred domiciles, would cost, including land, not more than two-thirds as much as one hundred separate houses of the same class, giving to each family the same amount and quality of habitable room. The edifice should be fire-proof, safer from intrusion, better drained, better ventilated, freer from offenses of all kinds, than the solitary houses. A finely-appointed kitchen, laundry, heating, lighting, and elevating apparatus, with telegraphic and other means of communication, sufficient for the wants of a hundred families, would replace one hundred sets of inferior work-rooms and apparatus in the separate houses. But one or more work-rooms would be provided in each domicile for minor or exceptional use.

The cost of carrying on the People's Household, including warming, lighting, water and food supply, cooking, and the laundry, with superintendence and general service, would not be *more* than two-thirds the cost of living in separate houses of the same class, all purchases being made at wholesale, and the work being performed by organized labor, using the best machinery. Each individual or family would be charged (perhaps against a monthly advance) for precisely what they consumed. The difference of cost between meals served in family alcoves of a great hall, or by dumb-waiter, or equivalent machinery, in each domicile, would be small, and, like all other arrangements, at the option of each proprietor. In previous experiments of this general character, it has not been found that any family would long prefer the more costly and inferior method of private purchase and labor in the departments of cooking and washing, although provision could easily be made for a limited use of the public machinery by individuals having such preference.

This estimate leaves to the women of each family the greater part of their time. Here is one of the greatest existing wastes of labor. *The separate house necessarily and permanently dooms woman to drudgery.* Under the present system she necessarily carries on a hundred trades every day by hand-work, as wasteful of productive force as the old spinning-wheel. The labor of women, saved in this way, would find new channels. The steam-power in the unitary building, in constant use for elevators, pumping, washing, cooking, heating, lighting, would always furnish a surplus of motive power for sewing-machines and small industries which would naturally grow up. In the People's Palace a Kindergarten for the youngest children, and schools more or less industrial and technical for those older, would have a natural and inevitable place. While this would still further relieve the mothers, it would also be a field for the occupation of women and men living in the Homestead who were specially gifted in these directions. Other collective work of the People's Home would give occupation to some of the inmates. Halls for lectures and social purposes, a library and reading-room, would also be among the endowments of every People's Palace.

Rising higher in the social scale, the question of domestic service, now so difficult of solution, would be summarily settled. In palatial buildings, occupying with inclosed and surrounding gardens a whole city square, erected with the wealth of a hundred rich families, nine-tenths of all the work would be done by the collective labor of employés, who would have no personal relations or contact with the individual proprietors. The remaining one-tenth of domestic service would admit of such selection and improvement of present methods as to get rid of the principal part of the evil. It is much easier to drill and actuate a corps of one hundred operatives in a public service than to direct a single domestic; and the elements of personal collision and suffering self-respect, inseparable from the latter rule, are absent from the former.

The Federative Homesteads, or People's Palaces, would especially need "Building Associations" for their establishment. But these associations would be neither charitable nor speculative; they would be mutual-insurance companies, not for rebuilding houses destroyed by fire, but to build each a palace, as perfect as modern art could make it, for the occupancy of its members, and subsequently to carry on the Palatial Household. The comparison of the Philadelphia system of separate houses, poorly constructed, and purchased by installments from building corporations not always purely mutual, should be made with such collective, self-owned homesteads, not with hired tenements, even should these be on the scale and with the appliances of the Peabody tenement-houses in London, erected by a magnificent charity.

The People's Palace, to replace the people's hovels, is no fanciful project or arbitrary contrivance, but the natural, inevitable form of the household required by our civilization, *corresponding strictly* with all our improved methods of productive industry; corresponding also with the social instincts and convictions of the time in which we live. Opposed to its practical introduction is the want of intelligence and mutual confidence in the masses, and also a selfish and exclusive spirit, which is short-sighted and defeats its own end. Witness the insecurity and ruinous waste of our separate households, the drudgery of women, and the slavery to servants. In agriculture witness also the loss of at least one-half the natural product by incoherent labor in the fields, and by the isolated farm-house and barn.[1]

I began this presentation of the "People's Palace" with the demand for an architecture and structural law which should throw around each individual and family a fortress of privacy, and which should secure a home-sphere more inviolable than is possible in our isolated houses, invaded daily by a horde of carriers, and pervaded by an alien caste of servants. This largest freedom and independence of the individual and family can only be assured by the perfect organization of the Homestead and Household.

In the vegetable and animal kingdoms the law of organization requires—1. The establishment of each individual molecule or cell in

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[1] Reference is here due to an American sociological novel, entitled "Papa's Own Girl," by Marie Howland, which furnishes a vivid description of the Familistère at Guise, and its supposed adoption in this country.

a world of its own; 2. The coördination and coöperation of such atoms or cells with each other, in a collective body or organism, according to their precise form and place. The want of either of these factors, the distinct individual units, or the scientific grouping and marshaling of units in a collective unity, deprives a body of its place in the organic world. The same factors must enter into every social organization which is entitled to the name. We have in this country an example of a true organization in our federative political system, composed of townships, counties, States, and nation, with its motto, "Out of many, one." I have drawn thence the designation *Federative* for the organized Homestead.

It is essential that relations of precise equity shall prevail between the proprietors of a Collective Home. The right of individual property in each domicile should be fortified by separate title and right of sale, subject only to chartered restrictions. In a well constructed and organized Federative Homestead such domiciles would always be salable at full cost value. A precise account, based on accurate standards of measurement, must be kept with each individual or family, including both general and special supplies and services. Instruction in the schools of the Palace would be classed among services to be specially accounted for. Our present common-school system (the best of our institutions) is a violation of social organic law, on the side of communism, to balance its violation in the opposite direction by incoherent industry and incoherent homes. The only scientific justification, if it may be so called, of the present system, is the rule that two wrongs make a right. The relation of highly-organized societies to children will, without doubt, be parental, through the recognition of new equities and the extension of mutual affection and service. But the further consideration of this subject does not belong here.

There are two extremes of reaction against existing society: one, Communism, its destructive fusion; the other, Individual Sovereignty, its destructive analysis. Each tends to social dissolution, because it rejects one of the organic factors. Between these extremes—occupying the domain of organization—are two possible social orders, one constructive, attractive in all its forces, coöperative, in harmony with modern thought, and with the development of science and the arts. The People's Palace is the natural form of household belonging to this order. The other is an inverted organization, compulsory, actuated by destructive rivalries, characterized by speculation and fraud, and feudal in its tendencies and results. To this latter order, the middle-age civilization of Europe and America, which still holds us, belong the isolated house and all in our present methods which insulate instead of associating the industries, and reconciling the interests of mankind. The single but sufficient means of resisting the communistic dissolution of our present society is to substitute everywhere for inverted methods natural organization, or, in other words, *scientific coöperation.*

The claim that the Federative Home, or "People's Palace," is the natural, inevitable form of the organized Household—coextensive with the future society—brings the subject within the domain of legitimate *social science.* The consideration of improved expedients for housing the people, without regard to the essential form and tendencies of civilization, is no part of social science, but only a discussion of the arts of life.

## RELATIONS OF HOSPITALS TO PAUPERISM.[1]

By W. GILL WYLIE, M. D.

CIVILIZATION has not reached that state of perfection where hospitals can be dispensed with. 1. As long as armies exist, hospitals will be necessary. Soldiers when sick must be provided with special accommodations; and, after a battle, the wounded cannot be properly cared for except in hospitals constructed especially for the purpose. 2. During epidemics of contagious and infectious diseases, it becomes a necessity to separate those infected from the well, and for their accommodation hospitals must be erected. 3. In every community, especially in large cities, there are always a certain number of paupers without any *homes*, who must be cared for when sick, and the only practical way of providing for them is to establish hospitals. 4. In large cities provision must be made for street casualties, and hospital accommodations are necessary. 5. On account of difficulty in making suitable provision for the insane in private houses, hospitals or asylums for the insane are necessary.

In this country, in all large cities, any one representing himself as poor and sick can apply either to the public hospitals supported by the State or to hospitals supported by voluntary contributions, and is admitted in many cases without any special inquiry or investigation as to his circumstances. In some places—as New York City—hospitals are so numerous, and admission to them so freely granted, that there is little or no restraint on impostors. If refused admission to one institution, they go to another and receive treatment and care without cost, when they are fully able to provide for themselves. And so numerous are the dispensaries where medicines and medical advice can be obtained free of cost, merely for the asking, and so easy and readily can care and attention be had in free hospitals, that the poor have no necessity to make provision for sickness.

It is estimated that about $10,000,000 are expended in public and

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[1] Extract from Boylston Medical Prize Essay, Harvard University, on "Civil Hospital Construction," 1876.

private charities annually in the city of New York, a city of 1,000,000 inhabitants. A considerable portion of this sum is expended on the hospitals, which alone contain more than 6,000 *beds*, not including insane or other asylums, but only institutions known by the name of hospitals. About 4,000 of the 6,000 beds are in public city or State hospitals, the remaining 2,000 being in hospitals supported by voluntary charity. The official reports of the thirty-odd free dispensaries give 307,060 as the number of patients applying for and receiving treatment in 1875 at the dispensaries, against 20,631 treated at their homes.

To say that $10,000,000 are expended in charities, that there are 6,000 free beds in the hospitals, and that over 300,000 persons receive medicine and medical advice free of cost at the dispensaries, is certainly evidence of the generosity and Christian spirit of charity that prevail. But, when looked at in a direct, practical way, these figures show something else. If these official reports are to be relied upon, then, in a population of 1,000,000, over 300,000 persons receive alms every year. We doubt if the number of individuals is so large, for it is the custom of some dispensaries to count each visit a patient makes as a patient treated. But the actual number is immense, and increasing out of all proportion to the increase of population. The truth is, the majority of our hospitals, *as they are at present managed*, are liable to do more harm than good. Apparently they do much good, and for the time do relieve suffering and want, but in the end may do much harm. Giving help too readily even during sickness is hurtful, and when it is offered freely without the certain knowledge that it is really needed, it very naturally removes the healthful stimulus of necessity, the dread of which prompts every individual to provide for the misfortune of sickness.

The dispensaries as they are now managed are nothing less than a promiscuous charity, exactly similar to the notorious "soup-kitchen"—medicine being substituted for soup. They offer to the ignorant and poor an easy and ever-ready inducement to take alms. They are the first stepping-stones to the degradation of pauperism. The self-respect of an individual is injured the moment he accepts alms, and a habit of taking alms invariably tends to a complete loss of self-respect and consequent degradation. It matters but little whether alms be medicine or food, the principle remains the same. The hungry must be fed; but we know that, instead of continuing to feed the hungry, and gradually destroying their power to help themselves, it is infinitely better to teach them how to help themselves and seek out and remove the cause that induced the miserable condition of helplessness. For exactly the same reason, would it not be better to teach the poor how to avoid getting sick, and by every means in our power remove the causes that induce disease among them, rather than to offer them the best care and attention without being sure that they need help, and thus teaching them to become careless about avoiding sickness?

It would be more creditable to the citizens of New York if they could say that no such institution as a pauper hospital was needed within the limits of the city than to be able to say that two hundred established charitable institutions and organizations are maintained; and instead of so many millions being spent in caring for the sick, would it not be better if the same money, or perhaps only a small part of it, were spent in carrying out sanitary works, and teaching the people the laws of health?

Suppose, during the prevalence of a contagious epidemic, the authorities should content themselves with providing for those infected, and neglect to take the necessary steps to remove the cause of the disease by doing all that sanitary science indicated—they would soon be called to account for neglect of duty. It is a well-known fact that the great majority of the cases of disease treated in our hospitals are induced by the bad sanitary condition of the homes of the poor, and to the direct violation, *through ignorance*, of the plainest hygienic laws; yet what direct steps are taken to correct this constantly-acting cause of sickness? The Health Department of New York City is expected to do little else than prevent epidemics of contagious and infectious diseases. The meagre appropriation prevents them from doing much more.

This statement concerning the charities of New York City cannot be called a fair example of the condition of the hospitals and other charities in smaller places, but it shows very plainly and truthfully the prevailing faults in the administration of charities throughout the country; and if the condition and results of the charities of smaller places are not so bad, it is due to local circumstances, and not to a better understanding of the subject, nor to the adoption of a more enlightened system.

The circumstances are very much in favor of the smaller cities and towns. Leaving out the many well-known causes that tend to generate pauperism, and thus increase the relative number of paupers in a large city that do not exist in towns or small cities, the main reason that charity does not do so much harm in the latter is, that the circumstances and the character of every one are well known to the people, and this personal knowledge guides and directs the givers of charity; whereas in the large cities it is seldom that the giver of charity knows to whom he is giving, and *personal knowledge* rarely exists at all. The difference between the lives of the rich and the poor is so great that the rich cannot comprehend the real needs of the poor. Unless these *personal relations* exist between those that give and those that receive, no act of generosity deserves the name of that charity which "blesseth twice," for gratitude is not developed in those receiving help. They give nothing in return for what they receive. Experience teaches that to do for an individual that which it is *possible* for him to do for himself will invariably tend to harm, unless he gives in return an equivalent, either by actual payment or in gratitude. And experience also teaches that human nature can only feel gratitude toward an individual.

Besides this tendency in hospitals as charitable institutions to increase pauperism, another serious objection to the use of public hospitals for the purpose of treating the sick beyond the extent absolutely demanded by necessity is, that every time an individual is removed from his home—let that home be ever so humble—and taken to a hospital, the family as an institution receives a blow.

Then, too, except to those already degraded, life in a pauper hospital, especially in the case of the young, is hardening to the feelings, while in many cases it subjects the moral to the influence of the immoral.

Another objection to hospitals is the bad sanitary condition of many of them, and unless this is improved, both as to the plan and the construction of the buildings, and the general and internal management, so as to give a smaller death-rate and fewer deaths from hospital-diseases than in the vast majority of hospitals now in use, it will be decidedly better, *on sanitary grounds alone*, to treat in their homes all the sick poor who have homes, even though they may be very bad and unhealthy places to live in. As to the expense of treating the poor at their homes, it certainly would not be greater than the expense of running the hospitals, if the interest-money is added which could be had from the immense sums that are sunk in the massive, many-storied hospital buildings, and the expensive city lots on which they stand.

But as poor-relief is now administered, and, no doubt, under the best system that could be devised, a certain number of hospitals for treating the sick poor will be necessary. When properly constructed and managed they are a great blessing to the poor, while, from the advantages they afford for the study and teaching of clinical medicine and nursing, they are of incalculable value to the whole community.

Since the establishment of the Training-School for Nurses in connection with St. Thomas's Hospital, by Miss Nightingale, in England, fifteen years ago, and, in this country, of the School for Nurses in connection with Bellevue Hospital, New York, three years ago, the great advantages of hospital-instruction are recognized for those who are studying nursing.

In the founding of hospitals, the question of their usefulness to medical education has not been given due consideration. As a rule, the idea of rendering immediate personal relief to the suffering poor is the first, and in many cases the only *acknowledged* object aimed at in establishing them.

The objections to civil hospitals as now stated may be said to be: 1. As institutions, they tend to weaken the family tie by separating the sick from their homes and their relatives, who are often too ready to relieve themselves of the burden of the sick and helpless of their family. Besides, when one or more of a family are removed those left at home are in an uncertain state of mind, and, in many instances, in an unprotected condition. 2. The inmates of pauper hospitals are liable to come in contact with bad influences: familiarity with suffering, unaccompanied by the *occupation* of relieving those who are suffering, ends in hardening the sensibility, especially in the young. 3. Like all public and general charities without the safeguard that personal knowledge affords, hospitals tend to foster idleness and helplessness, and their natural results, pauperism and crime. 4. When badly constructed or badly managed, they are liable to cause hospital-diseases among the inmates, and become centres of infection, thus defeating the very object they are intended to promote.

On the other hand, the arguments in favor of civil hospitals are: 1. They are a necessity under many circumstances for giving shelter to the sick and helpless, and are supposed to be the most economical method of providing for the sick poor. 2. They are of very great value as affording an opportunity for the comparative study of diseases, and for giving practical instruction in the science of medicine and the art of nursing to the greatest advantage, and thus, by helping directly a few individuals, indirectly rendering a service of incalculable value to the world. 3. During contagious epidemics they are a ready means of providing for those who are infected, and, by their isolation, preventing the spread of disease.

As means toward checking the undesirable multiplication of expensive institutions, toward preventing hospitals from breaking up or interfering with the family tie, and at the same time to keep them from engendering pauperism, we suggest: 1. Do all that can be done to enlighten the poor to help themselves, and to avoid the causes of disease. 2. Give indirect help by improving the condition of the homes of the poor, by strict laws in regard to the existence and building of all dwelling-houses, manufactories, schools, etc., etc., and in regard to the sale of food. 3. Limit hospital accommodations to those who have no homes, and to those who cannot be assisted at their homes.

It is doubtful if the state can give direct out-door help, even medical help, without doing more harm than good. It can only be done wisely by establishing a Bureau of Intelligence in connection with the police department, with offices at each police station, where the names and the numbers of the inmates in every house in the precinct or district would be known, and where, from personal knowledge, a record of all individuals receiving help—as to their circumstances, the amount of aid given, etc.—would be kept. As far as possible, all help rendered should be guided by this knowledge, and it should be obligatory on all charitable institutions and associations to give information of all assistance rendered by them to individuals living in the district.

Through this Intelligence Bureau reliable personal knowledge of every applicant for hospital-relief could be obtained. We fully appreciate the great difficulty of organizing and uniting voluntary charities in this country, where there are so many different religious sects; but by establishing such a system as the above much could be done toward distributing help where it is really needed, and toward preventing indiscriminate charity, and in detecting impostors. To avoid the injurious moral effects of hospitals on the characters of the inmates, and to prevent such bad sanitary conditions in hospitals as are sure to result in retarding cures, and often in the generation of fatal hospital-diseases, it is necessary to have hospitals constructed and managed in accordance with the teachings of sanitary science.

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## GEORGE HENRY LEWES.

THIS versatile thinker, known to science by his "Seaside Studies" and his "Physiology of Common Life"—works of much originality—as well as by his "History of Philosophy" and his "Problems of Life and Mind," in which he puts forth independent views on scientific methodology, was born in London, April 18, 1817. At an early age he was sent to the Continent of Europe to receive an education, but returned while still a lad, and was then placed under the tuition of Dr. Burney, at Greenwich.

The influence of his residence abroad, during the impressionable period of boyhood, is seen in a greater degree of vivacity than is usual among his countrymen. On leaving school young Lewes became a clerk in a mercantile house, but, as his tastes inclined him rather to a literary and scientific than a business career, he left the counting-house and took up the study of anatomy and physiology. His interest in these sciences appears to have sprung purely from a thirst for knowledge, as he did not purpose to become a physician. As early as 1836 he had in contemplation a treatise on the philosophy of mind, in which the doctrines of the Scotch metaphysicians—Reid, Stewart, and Brown—were to be physiologically interpreted, and, during the following year, he gave a course of lectures upon this subject. The investigations made at this time were destined to be suspended for a while, but later to be resumed and pushed forward into the most difficult provinces of philosophical inquiry. The years 1838 and 1839 he spent in Germany, devoting himself with characteristic assiduity to the study of literature and philosophy. Besides acquiring a mastery of the German language, he gained an intimate acquaintance with German habits of thought. Even in his boyhood he was an indefatigable bookworm, and residence in Germany tended only to strengthen him in this habit, and to make him one of the most versatile writers and at the same time one of the most diligent students of the day. On his return to England, he for the first time felt, as he said, fully confident to enter on his career as a *littérateur*. He contributed to the columns of the daily press reviews and criticisms of books, and to the quarterly reviews and the leading literary magazines of England scientific and philosophical essays, biographical sketches, and the like. In 1849 he assumed the literary editorship of the *Leader* newspaper, which post he held till 1854. A London correspondent of an American journal, referring to this period of Lewes's life, says: "His criticisms, as indeed all his writings, were noted for piquancy, brilliancy, and boldness of thought. He had not only no objection to expressing his opinions; he was determined that the public should know them if they were capable of comprehending pungent and forcible English. He has never been a man with moral or mental reservations. As soon as he has a new thought, a new conviction, a new theory, he blurts it out. He was not long in making his mark, and from that time to the present, whatever has emanated from him has attracted attention and awakened interest." In 1865 he founded the *Fortnightly Review*, but was compelled by ill health to resign the editorship the following year; he was succeeded by John Morley.

His first elaborate work—a work which affords ample evidence both of his laborious industry and of his keen insight—was the "Biographical History of Philosophy, from Thales to Comte," first published in 1845. A fourth edition, corrected and partly rewritten, appeared in 1871 (2 vols.). An acute French critic says of this work of Mr. Lewes: "His history resembles rather that of Hegel than that of Ritter. His review of the labors of philosophers is rather occupied with that which they have thought than with their comparative importance. He judges rather than expounds; his history is fastidious and critical. It is the work of a clear, precise, and elegant mind, always that of a writer often witty, measured, possessing no taste for declamation, and making its interest profitable to the reader whom he forces to think. This is no ordinary history of philosophy; it is the work of an original mind which has a great deal to say, and yields voluntarily to the pleasure of saying it, a mind which handles texts like a thinker, not like a scholar. Assuredly we must not search Mr. Lewes's pages for enlightenment upon obscure points and upon controverted passages; but in this long journey from Thales to Comte the author has taken amazing pains, and has put forth enough teaching to content some, to leave others discontented, and to make every one reflect" (Ribot, "English Psychology"). In the preface to this history Mr. Lewes offers the following definition of the limits of theology, philosophy, and science: "Theology, philosophy, and science," he writes, "constitute our spiritual triumvirate. . . . Its [theology's] main province is the province of feeling; its office is *the systematization of our religious conceptions.* The office of science is distinct. It may be defined as *the systematization of the order of phenomena considered as phenomena.* The office of philosophy is again distinct from these. It is *the systematization of the conceptions furnished by theology and science*—ἐπιστήμη ἐπιστημῶν (the science of sciences). This "History of Philosophy" was commenced by its author with the definite purpose of showing the radical weakness of all metaphysics. "The history of philosophy," he writes, "presents the spectacle of thousands of intellects—some of the greatest that have made our race illustrious—steadily concentrated on problems believed to be of vital importance, yet producing no other result than a conviction of the extreme facility of error. The only conquest has been *critical*, i. e., physiological." His opinion of the value of scientific methods in philosophical inquiry is expressed in the following passage: "There are many who deplore the encroachment of science, fondly imagining that metaphysical philosophy would respond better to the higher wants of man. This regret is partly unreasoning sentiment, partly ignorance of the limitations of human faculty. Even among those who admit that ontology is an impossible attempt, there are many who think it should be persevered in, because of the 'lofty views' it is supposed to open to us. This is as if a man, desirous of going to America, should insist on walking there, because journeys on foot are more poetical than journeys by steam. He dies without reaching America, but to the last gasp he maintains that he has discovered the route on which others may reach it." In 1853 Mr. Lewes contributed to Bohn's "Scientific Library" a volume entitled "Comte's Philosophy of the Sciences."

Five years later (1858) appeared his "Seaside Studies at Ilfracombe." For the meeting of the British Association, the same year, he prepared a paper on "The Spinal Cord as a Centre of Sensation and Volition;" in 1859 he published three papers on "The Nervous System," in which he combated the received doctrines. These papers gave rise to a warm discussion among British physiologists, and even attracted much attention on the Continent of Europe. The "Physiology of Common Life" appeared in 1860, and in the following year was published "Studies in Animal Life." The object of these researches into the nervous system of animals and man was, as he informs us in the preface of his latest work, to obtain the clew through the labyrinth of mental phenomena. Misled by the plausible supposition that the complex phenomena in man might be better interpreted by approaching them through the simpler phenomena in animals, he began to collect materials for a work on animal psychology. But he was not then aware that, rightly to understand the mental condition of animals, we must first gain a clear vision of the fundamental processes in man; for it is only through our knowledge of the processes in ourselves that we can interpret the manifestations of similar processes in them. Here again we are hampered by the anthropomorphic tendency which leads us to assign exclusively human motives to animal actions. In 1864 he published "Aristotle: a Chapter from the History of Science," with analyses of the Stagirite's scientific works. This work was republished in 1873. Since that time he has published, in two volumes, the first series of "Problems of Life and Mind," which was noticed in the MONTHLY, No. 42. The other published works of Mr. Lewes are: "Ranthorpe—a Tale" (1847); "The Spanish Drama," and "Rose, Blanche, and Violet," a novel (1848); "The Noble Heart," a tragedy, and a "Life of Robespierre" (1850); "Life and Works of Goethe" (1855), indisputably the best work on the subject. Besides these separate volumes he is, as has been already stated, the author of a multitude of essays, reviews, criticisms, etc., in the periodical press.

Personally, Mr. Lewes is described as rather small in stature. His face gives no very clear indication of the mental power he unquestionably possesses. His health has always been infirm, and he looks older than he is. From his portrait, one might imagine Lewes to be a man accustomed to life out-of-doors, though he has always been a close student and a resident of London, or other large capitals. His manner differs markedly from that of the generality of Englishmen. "In his own set," writes the newspaper correspondent already quoted, "he abounds in geniality and *bonhomie.* He does not remind you of an Englishman; he has none of the hesitation or drawl so typical of his nation, but talks with marked ease and fluency and radiance. He is fond of epigram and paradox, and, being a close observer, his narration of men and things is extremely entertaining. He has the reputation of being one of the most brilliant conversationalists in London, though, like most clever talkers, he is prone to monopoly and monologue." As an author he is slow and painstaking, and the longer he lives the more careful and conscientious does he become in this respect. He does not believe that thoughtful and growing men acquire facility with years, and says that when he was forty he would do four or five pages in the time now required for one. Some years ago he married the eminent novelist, Marian Evans, known to fame as George Eliot. They live in one of the suburbs of London, and their home is represented as being one of the happiest, the likeness of their pursuits and ambitions being an additional bond of unity.

# CORRESPONDENCE.

### ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

*To the Editor of the Popular Science Monthly.*

At the risk of appearing ungracious, and possibly fastidious, I beg leave to invite attention to some inaccuracies in a brief notice of the Academy of Natural Sciences of Philadelphia, published in The Popular Science Monthly for August, 1876. The statements are erroneous; and, taken as a whole, the article does not fairly present the Academy to the public. The enthusiasm of my learned friend Prof. Cope has possibly led the writer of the article into misconception.

The Popular Science Monthly says, in substance, that Prof. E. D. Cope availed himself of the occasion of the Academy's taking possession of its new building "to suggest in the *Penn Monthly* some needed changes and improvements" in the organization of the society.

Prof. Cope, in his article on "The Academy of Natural Sciences" in the *Penn Monthly*, mentions that the Academy while changing its location revised its organization, "adding some functions which shall" relate it to the public more nearly than heretofore; that "its founder," meaning, of course, its seven founders, designed that the objects of the society should be promotion of original research, of instruction, and of the diffusion of knowledge.

Prof. Cope, Corresponding Secretary of the society, and at the period referred to one of a committee instructed to revise the by-laws with a view to improvement, did suddenly conceive and hastily deliver to the public press, contrary to the usual practice in such cases, an article referring to matters which were under consideration of the committee at the time, possibly in expectation that a small minority on some points of peculiar interest might be made a majority through the influence of his eloquence.

The Popular Science Monthly says that the Academy has "a moderate fund for promoting" the diffusion of knowledge, and regularly publishes "Transactions."

The Academy has a very modest "publication-fund," but it has never put forth anything under the title of "Transactions." It publishes the *Journal of the Academy of Natural Sciences of Philadelphia* (quarto), and the *Proceedings of the Academy of Natural Sciences of Philadelphia* (octavo), the first now including 6,592 pages and 565 plates, and the second, 10,692 pages and 136 plates, which together constitute the Academy's records of original research.

"Original research is not materially encouraged by the Academy."—The Popular Science Monthly.

Original research is considerably encouraged by publishing the reports of investigators, and by giving them freely the use of a scientific library of 25,000 volumes, and of extensive collections of natural objects while engaged in their work. If it is meant that the Academy does not encourage original research because it does not feed, lodge, and clothe investigators, or pretend to compensate them in any manner for scientific work, the charge must be admitted. It may truly plead, however, in extenuation of the illiberal policy of which it is accused, that its resources have never exceeded its current expenditures for fuel, light, postage, freight, etc., etc. The Academy is accused, indirectly, with doing less to encourage original research than might be done with its means: "for," says The Popular Science Monthly, "in one instance funds, supposed to be devoted to research, were hoarded, and afterward turned over to the building-fund."

The Academy never had funds which were in fact or "supposed to be devoted to research." The assertion to the contrary is not true. A section of the Academy had a surplus accumulation in its publication-fund, and generously contributed a part of it to aid the Academy to finish its building. The members of that section are as earnest in the promotion of the interests of science and of the Academy, and as intelligent in the application of their means, as the gentleman who makes their gift the basis of an accusation of dereliction of duty against the Academy.

THE POPULAR SCIENCE MONTHLY says, "Less than five hundred dollars per annum is devoted to 'instruction.'"

For this purpose the Academy expends $480, the entire proceeds of a fund bequeathed to it for this object. Is it reasonably honest to make it a fault that it does not spend more for a specific purpose than it has to spend?

Again, "The chief fault found by Prof. Cope in the organization of the Academy is that, while it secures good financial management, it minimizes the scientific features of the body." And, as if to sustain the assertion that the organization minimizes the scientific features of the body, we are gravely assured, in a somewhat contemptuous manner, in the words of Prof. Cope, that "its officers are the usual president, vice-president, secretary, etc., constituting a management as appropriate to an historical society, library company, or, I might add, church vestry, as to an academy of natural sciences. It has no position designed for its distinctive and essential feature, its scientific experts."

Since its foundation the organization of the society has been frequently and carefully revised. In 1858 provision for the formation of departments, which were called sections in 1868, was made. About six years ago a council was added to it, and in May last the council was enlarged, and authorized to elect thirteen professors, but no source of compensation or rate of compensation has been provided for them. Positions for its scientific experts have been thus provided. In this revision of the organization it was considered to be not expedient at this time to dispense with president, vice-presidents, secretaries, treasurer, etc., although it is freely admitted that these officers are as appropriate to a church vestry as to an academy of natural sciences.

It is made the duty of each professor to preserve, classify, and increase the collections in his department, and report annually their condition and needs to the council, to give special or objective instruction to the beneficiaries of the scholarships in the Academy, and to deliver courses of lectures, under such regulations as the council may establish.

If any properly-qualified gentleman is willing to assume the duties of a professorship without pecuniary compensation, his services will be cheerfully accepted, and he will be encouraged to pursue original investigations as far as can be done without money. It is conjectured, however, that competition for these chairs will not be very active until they are adequately endowed.

The old building was universally admitted to be crowded to excess, and that more space was needed for the collections as well as for the library. Prof. Cope speaks of the collections, and considers them, with one or two exceptions, as extremely meagre, and tells us that a great museum of the future, to be complete, should contain 10,000,000 species of animals, represented by "several specimens of each," aggregating from 30,000,000 to 50,000,000 specimens, adding in the sequel that all the money spent on the new building would have been "as well spent in endowing chairs in the old locality."

In spite of the authority of Prof. Cope's opinion thus implied, that the old building was large enough, it is now found that a half-million of specimens cannot be satisfactorily displayed in the new edifice, though it is twice as capacious as the old one. There is already urgent demand for more space, and this is so evident that contributions to the building-fund have been recently made with a view to an immediate completion of the edifice conformably to the approved plans of the architect. No one thing which can be done now is likely to promote the prosperity of the Academy in the future to a greater degree than to finish the building without loss of time. Efforts to augment the collections will not be very earnest, nor successful in result, until there be accommodation for additions which may be made to them. Original investigation will be more active in the Academy when it can offer a well-appointed laboratory for the use of workers; and an apartment suitably furnished to accommodate an audience, and enable the professors to illustrate their teachings, is prerequisite to the delivery of systematic courses of popular or elementary lectures on natural science in the Academy. The completion of the building will facilitate and strengthen all the functions of the society in all its departments, and lay the foundation of a workshop in which experts and students may pursue investigations advantageously to science and themselves.

The progress of the Academy has been always deliberate and unobtrusive. It will so continue until accelerated by enlarged resources.

To the full extent of its means the Academy encourages original research, gives instruction to those who seek it, and promotes the diffusion of knowledge. Its doors are never closed against a student or votary of science; every one is cordially welcome, and given such assistance and facilities as the society has, which are all charitable gifts, benevolently aggregated and preserved here for the benefit of the intellectually hungry. It may be safely conjectured that its usefulness will increase, *pari passu*, with the augmentation of its pecuniary resources, unless Utopian projects of scientific grandeur and exclusiveness be injected into its policy.

Observance of that wise and holy precept, *suum cuique*—to Cæsar the things which are Cæsar's—relatively both to substantial things and mental products, would save us all a world of trouble and vexation. Commending the consideration of this precept to my readers most cordially, I am,

Very respectfully,

W. S. W. Ruschenberger.

Philadelphia, *August* 1, 1876.

## LIMITS OF THE WESTERN GRASSHOPPERS' RAVAGES.

*To the Editor of the Popular Science Monthly.*

In The Popular Science Monthly for July I find the statement quoted from Prof. Riley that the southern limit of the locust ravages is the 44th parallel of latitude, and the eastern limit the 103d meridian. The latitude of this place is 39° 52′ nearly. As I write, the locusts are flying so thickly as to give sunlight the yellow tinge of dense smoke. Last night, in a single hour, whole fields of barley were eaten to the ground, and the fields swept cleaner than the harvester could have done the work. These ravages to-day extend one hundred and twenty-five miles south of this place, or to latitude 37°, and how much farther the news has not reached me. Their appearance here is neither unexpected nor exceptional. During the three preceding years agricultural products throughout Colorado were almost entirely destroyed, and thousands of farms were financially ruined. They have visited us to a greater or less extent annually for the last twelve years, and their ravages have often extended as far east as Lawrence, Kansas, or two hundred miles east of the line prescribed in the article referred to. Our altitude is 8,300 feet above the ocean, but this is not their limit. A few days ago I was on a mountain-summit, 14,000 feet in height, and there they were flying to the westward, high overhead, in immense clouds. Many plans are resorted to for their destruction. Kerosene dripping slowly upon the water in irrigating ditches is very effective. Traveling machines, filled with fire, passing over the ground like mowers, destroy millions; but when they come in clouds, as to-day, I know of no defense at all adequate.

I have driven them a hundred times to-day from the little twenty-foot green spot in front of my house, and yet there are as many there as if I had done nothing. Fortunately they are fastidious, and often will not eat grass, potatoes, or oats.

There is one remedy which I believe would be effective, and that is the preservation of prairie-grouse and other insectivorous birds. The number of locusts eaten by prairie chickens and quails is perfectly marvelous. For the destruction of hawks and eagles there should be a reward offered by the State. This would preserve many of the birds; and heavy fines imposed for the destruction of birds, at any time of the year, would work the rest.

As long as Colorado, Kansas, and Nebraska, permit the unlimited slaughter of these, their best friends and preservers, they deserve to suffer from the devastation of the locusts, or grasshoppers, as we call them. Respectfully yours,

D. C. Collier.

Central City, Colorado. *August* 10, 1876.

## ACCIDENTAL VARIATION.

*To the Editor of the Popular Science Monthly.*

The following figures and description show a somewhat interesting case of accidental variation:

The antlers are those of a common deer (*Cervus Virginianus*). The buck from which they were taken was about five years old, and was shot by a gentleman of long and varied experience as a hunter; he thinks them quite exceptional in shape.

Fig. 1.

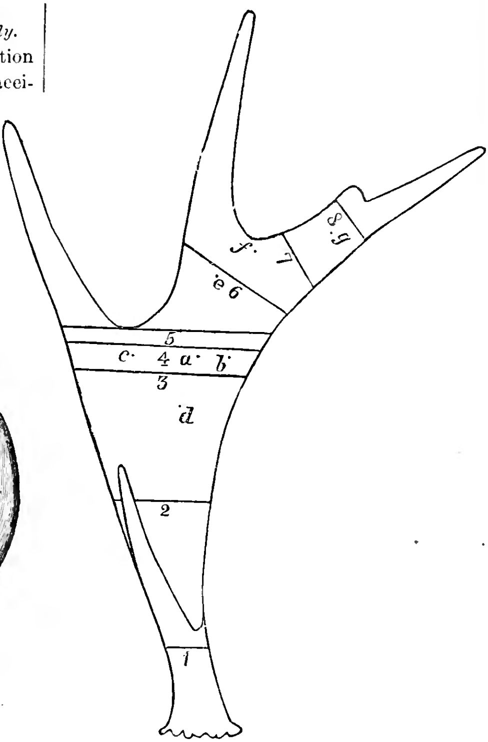

Fig. 2.

In their dimensions and their great width, as compared with thickness, they show a strong resemblance to the palmated antlers of the caribou, or an approach to the antlers of the elk.

Fig. 1 shows the position and curvature of the antlers. As indicated, they differ somewhat in outline, and the left one is shorter and broader than the right.

Fig. 2 is a reduced sketch obtained by tracing the outlines of the left antler on a large sheet of paper, and then corrected by careful measurements with calipers.

The measurements are:

| | | |
|---|---|---|
| Width from tip to tip | 15⅜ | inches. |
| Length of exterior curvature from root to tip | 18¾ | " |
| Direct height | 11¼ | " |
| Width at 1 | 1⅜ | " |
| " 2 | 2¼ | " |
| " 3 | 4⅛ | " |
| " 4 | 4⅞ | " |
| " 5 | 7⅛ | " |
| " 6 | 3 | " |
| " 7 | $1\frac{3}{16}$ | " |
| " 8 | 1⅝ | " |
| Thickness at *a* | ⅞ | inch. |
| " *b* | ½ | " |
| " *c* | ⅝ | " |
| " *d* | ⅞ | " |
| " *e* | ¾ | " |
| " *f* | $\frac{9}{16}$ | " |
| " *g* | ⅞ | " |
| Girth at root of antler | 5⅜ | inches. |
| " 2 | 5⅝ | " |
| " 4 | 10⅛ | " |
| " 7 | 4⅜ | " |
| " 8 | 4⅛ | " |

E. R. Leland.

Eauclaire, Wis., *June* 19, 1876.

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## WHO ERECTED STONEHENGE?

*To the Editor of the Popular Science Monthly.*

When a boy, the writer walked many miles to visit Stonehenge. He was utterly alone with these hoary ruins on that treeless plain, and retains, after a third of a century, a vivid reminiscence of the scene and its suggestions.

The attribution of these remains to the

Druids always seemed to him quite as absurd as if a discoverer of the mounds of the Mississippi Valley should credit them to the medicine-men of the Indian tribes who alone were found in their vicinity.

Neither Cæsar nor any other ancient author found in the Keltic population of Britain any indication of either the skill or the numerical force commensurate for such undertakings.

The vast slabs composing the circles of Stonehenge are now, it is true, as they were no doubt in Bede's time, shapeless, *with one notable exception.*

Some of the slabs which have more recently, say within a thousand years, lost their lintels exhibit the unique feature of a duplex tenon, while the lintels show the corresponding mortises. Now this dovetailing, so to speak, of masonry, shows architectural skill and genius of a high order—immeasurably ahead of anything the Kelts were capable of; nay, more, in advance of even modern art in this department. Further, the material of Stonehenge must have been transported many scores of miles. A people so advanced as to mortise their masonry would scarcely have left the exterior surfaces unchiseled.

The tenons were protected in their inclosing mortises, while the storms of, it may be, two hundred centuries rasped off all vestige of the pristine beauty of their exteriors.

G. H. KNIGHT.

CINCINNATI, *August* 23, 1876.

# EDITOR'S TABLE.

## *FURTHER CONCERNING THE "SOUND" CONTROVERSY.*

SOME months ago, as our readers will remember, there appeared in the *Nation*, by an anonymous writer, a scandalous attack upon Prof. Tyndall. He was accused of treating Prof. Henry dishonorably; and the accusation was so garnished with insulting insinuations as to convey the impression that Prof. Tyndall is not above ignoring and suppressing other people's valuable work which he desires to profit by himself. It was a matter of painful surprise to many that any man could be found, in this country, to make such charges on no better grounds than were alleged against an eminent and absent gentleman of hitherto unsullied character; or that any respectable American newspaper would lend itself to their publication. For this was one of those palpable cases in which some decisive weight should have been allowed to character at the outset. While on the one hand charges were raised of which the proof was not furnished, and a specious case was made out by unscrupulous ingenuity which was calculated to mystify and prejudice ordinary readers, on the other hand the imputations against Prof. Tyndall were specially contradicted and discredited by the quality of his whole life. He was eminently not the man to do the things alleged. The intimate friend and successor of Faraday, and for the last twenty-five years Professor of Natural Philosophy in the Royal Institution of Great Britain, his life and works have been in an eminent degree public and conspicuous. An assiduous investigator in various branches of physics, he has published freely in the Transactions of the Royal Society; a clear and vigorous writer, appreciating the necessity of improving popular scientific literature, he has also written copiously for the public, on many of the most recent and exciting questions of science. Perhaps there is not another eminent man of science, in any country, whose intellectual life has been more open to scrutiny than that of Prof. Tyndall. Yet with this prolonged and intense exposure of his mental work to a world sufficiently censorious—and though often in sharp conflict with other investigators—his reputation as a man of the strictest honor in relation to all the rights and claims of his scientific co-laborers has been unquestioned.

Moreover, those best acquainted with Prof. Tyndall know that his solicitude in doing justice to his scientific brethren, as evinced in difficult circumstances, is so earnest as to be almost morbid. No man is freer from petty jealousies, or the narrowing influence of national bias, than he. Attaching a serious meaning to the common sentiment that "science is of no country," he has stemmed the violent currents of local feeling in his own, and aimed to be just and generous to foreigners when their claims have been depreciated by British scientists. This is perfectly understood by all who are familiar with recent scientific controversy. His championship of the German Mayer, the Savoyard Rendu, and the American Agassiz, when their rights as discoverers were denied by his own countrymen, showed the breadth of his sympathies and the strength of his sense of justice. Nor is it improper here to add that he came to this country to help on the work of science, moved by no low or sordid considerations. He resisted social solicitations in a way that was not a little misinterpreted, that he might do the work he had undertaken in the best manner; and contributed all that he got from half a year's hard labor to assist in the scientific education of worthy young men of this country for whose special aid there had been, hitherto, no provision.

We submit that these considerations should have been sufficient to protect Prof. Tyndall from the gross assault in the *Nation*, which could not be replied to until a sensation-seeking press had scattered the calumnious charges from one end of the country to the other. Something, we say again, was due to character, that should have prevented the diffusion of such aspersions until they had been thoroughly looked into, and the party most concerned had been consulted. We appeal to every candid reader, if it would not have been a fairer proceeding for the editor to have sent the article to Prof. Tyndall, if he thought it worth attention, and to have asked him what it meant, that the defense might have accompanied the attack, had he still thought the matter proper for publication.

The case has now assumed a different aspect. The anonymous writer in the *Nation* has recently rehashed and amplified his statement, put his name to it, and published it in the *New York Tribune*. It is noteworthy that, while the writer announces himself to have been an assistant of Prof. Henry, he recognizes the necessity of disavowing all complicity on the part of that gentleman in these assaults upon Tyndall. It would have been well if this had been thought of a little earlier; and there is no reason for the disclaimer now that should not have impelled Prof. Henry to protect himself from misapprehension, by following the publication of the article in the *Nation* by a prompt statement of the fact that he had nothing whatever to do with it.

With the larger portion of the communication to the *Tribune* we have no concern, as its four closely-printed columns are chiefly occupied in trumping up new and petty imputations against Prof. Tyndall that are wholly unworthy of notice. Borrowing a hint from the tactics of our political canvass, the writer seems to think that the way to substantiate one charge is to pile up more. But the case, as now even more fully presented, has not a leg to stand upon. In fact, the writer has put an end to it himself by attempting to give his proofs. We have said that the article in the *Nation* made charges without giving the evidence; that evidence is now forthcoming, and, as we shall see, instead of sustaining, refutes the charges and explodes the case.

Prof. Tyndall had said in his book on "Sound" that Dr. Derham's paper, published in 1708, and which contains the views which have generally prevailed upon the subject since, "*marks the latest systematic inquiry into the causes which affect the intensity of sound in the atmosphere*," up to the time of his own investigations in 1873. This period he characterizes as a *blank*. He does not deny that facts of importance had been observed in the interval, or that partial inquiries had been made leading to valuable conclusions; but the "blank" is declared to consist in the absence of any "systematic inquiry into causes," such, of course, as generally lead, when ably conducted, to the reconciliation of conflicting views, and the establishment of principles which are entitled to take their place in the body of scientific knowledge. To this the writer in the *Nation* replied that Prof. Henry had made such systematic inquiries, and that Prof. Tyndall knew it from a paper which he heard Prof. Henry read in Washington. The evidence of the charges against Prof. Tyndall of "ignoring" or "suppressing" the work of Henry, or of taking advantage of it in his own subsequent investigation, is, therefore, to be found in this paper, if anywhere. The writer of the article in the *Nation* did not adduce the article, although his whole case rested upon it. Challenged for his evidence, he now brings it forward in the *Tribune*, makes extracts from it, and states what else it contained; and we now give his whole reference to it, italics and all:

"Prof. Henry prefaced his paper on that occasion with the following reference to Dr. Tyndall's presence: 'The communication which I propose to make this evening is brought forward at this time especially on account of the presence of Dr. Tyndall, he being connected with the lighthouse system of Great Britain, while the facts I have to state are connected with the lighthouse service of the United States, and must therefore be of interest to our distinguished visitor. The facts I have to present form part of a general report to be published by the United States Lighthouse Board.'

"After briefly treating on the prevalence of fogs upon the American coast, Prof. Henry proceeded to consider their scientific relations to fog-signaling, and remarked as follows:

"'In studying this subject it becomes a question of importance to ascertain whether waves of sound, like those of light, are absorbed or stifled by fog; on this point, however, observers disagree. At first sight, from the very striking analogy which exists in many respects between light and sound, the opinion has largely prevailed that sound is impeded by fog. But those who have not been influenced by this analogy *have in some instances adopted the opposite opinion that sound is better heard during a fog than in clear weather.* To settle this question definitely the Lighthouse Board have directed that at two lighthouses on the route from Boston to St. Johns the fog-signals shall be sounded every day on which the steamboats from these ports pass the station, both in clear and foggy weather, the pilots on board these vessels having, for a small gratuity, engaged to note the actual distance of the boat when the sound is first heard on approaching the signal, and is last heard on receding from it. The boats above mentioned estimate their distance with considerable precision by the number of revolutions of the paddle-wheel, as recorded by the indicator of the engine, and it is hoped by this means to definitely decide the point in question. We think it highly probable that fog does somewhat diminish the penetrating power of sound, or, in other words, produce an effect analogous to the propagation of light. But when we consider the extreme minuteness of the particles of water constituting the fog, as compared with the magnitude of the waves of sound, *the analogy does not hold except in so small a degree as to be of no practical importance, or, in other words, the existence of fog is a true, but, we think, an insufficient, cause of diminution of sound, which view is borne out by the great distance at which our signals are heard during a dense fog.* Another cause, which without doubt is a true one, of the diminution of the penetrating power of sound is the varying density of the atmosphere, from heat and moisture, in long distances. The effect of this, however, would apparently be to slightly distort the wave of sound rather than to obliterate it. *However this may be, we think, from all the observations we have made, the effect is small in comparison with another cause, viz., that of the influence of* WIND. During a residence of several weeks at the sea-shore, the sound of the breakers at a distance of about a mile in no case appeared to be coincident with the variations of an aneroid barometer or a thermometer, but in every instance it was affected by the direction of the wind. The variation in the distinctness of the sound of a distant instrument as depending on the direction of the wind is so marked *that we are warranted in considering it the principal cause of the inefficiency in certain cases of the most powerful fog-signals.*'

"In the remainder of his paper, as read in the presence of Prof. Tyndall, the chairman of the Lighthouse Board applied the hypothesis of Prof. Stokes to an explanation of certain abnormal phenomena of sound which had been observed during the course of his systematic inquiries with regard to the causes which affect the intensity of sound."

The reader now has the whole case before him. This is the substance of what Prof. Tyndall listened to in Washington, and for not recognizing which, to the credit of American science, in his book on sound, he has been the subject of a bitter and persistent newspaper attack. Prof. Tyndall says that the reading of the document left him in mental perplexity, and we are certainly not surprised at his state of mind. The subject, it is to be remembered, was not new to him. He had been for years engaged in the scientific service of the English Lighthouse Department; he had been an explorer in the field of acoustics, and was familiar with the history of the subject. He knew that it was involved in obscurity, that observations disagreed, and that there was much theoretical conflict about it. Nothing seemed established, and he states that Prof. Henry's paper left him still in an intellectual fog in regard to the whole question. The reader will see that the statement is pervaded by doubt. Conflicting opinions are given, and the prominent question was yet to be decided by the aid of Boston pilots. Finally, a conjecture, thrown out by an English physicist, is invoked for the explanation of anomalous effects observed. Clearly it was a case for further and formidable work which required to be met by a comprehensive, systematic, and thorough-going research. Prof. Henry's paper settled nothing. That it was without value as a contribution to science, we by no means assert; but every one can see that it was not the product of a full, methodical, and exhaustive inquiry, such as the subject urgently demanded and had not yet received from any source. The observations of Humboldt, early in the century, on the passage of sound, were important, as Prof. Tyndall himself attests, but to characterize them as a "systematic inquiry into the causes which affect the intensity of sound in the atmosphere" is simply absurd. Humboldt confined himself to one branch of the investigation, and whole tracts of it he did not touch.

Prof. Tyndall was, therefore, abundantly justified in assuming that the blank of 167 years had not been filled up; and, being deeply interested in the subject, and having command of the means for an elaborate course of researches upon it, he determined to enter fully into the inquiry, with the hope of dispelling some of the uncertainty which clouded it.

He took up the question from a purely scientific point of view, not to improve the art of fog-signaling or arrive at any immediate practical results valuable to the navigator, but simply to test theories, explain phenomena, harmonize discrepancies, and advance acoustical science. He attacked the problem of the "causes" which affect the intensity of sound in the air with a single-mindedness, a rigor of method, and a completeness of resources, that had never before been employed upon it. His researches went on in a double series, on the coast and in the laboratory. Using the facilities furnished by the Government at home, and sending abroad for the best that could be supplied, he carried on his observations and experiments on a large scale from the South Foreland Station, scrutinizing and testing the various views and suggestions that had been proposed, and arriving at new and important conclusions in regard to the causes of which he was in search. He then subjected these conclusions to elaborate experimental verification by newly-devised apparatus, and original researches in the Royal Institution, with the attainment of results which will probably take their permanent place among the principles of acoustical science. At any rate, the subject, with its accumulated difficulties, had never before received so efficient a sifting and overhauling; and it was this that Prof. Tyndall meant, and had a right to mean, by the phrase "systematic inquiry into causes," in which he characterized his work. The writer in the *Tribune* can entertain his own views as to what that phrase signifies in dealing with the phenomena of Nature, but Prof. Tyndall will be perfectly easy in leaving this matter to the judgment of scientific men.

### *THE AMERICAN ASSOCIATION AT BUFFALO.*

The meeting of the American Association for the Advancement of Science, which began August 23d and lasted a week, has been unusually successful. There was a strong attendance of members, and a greater number than at any previous session of foreigners distinguished in science. A large number of papers were contributed to the proceedings, several of them important and of marked originality. Prof. Rogers presided with characteristic dignity and grace, and the retiring president, Prof. Hilgard, gave an instructive address, devoted mainly to his own department of study, and giving a sketch of the progress of the scientific measurements and mapping of the earth.

And the meeting was a success socially as well as scientifically. The citizens of Buffalo extended their hospitality in the most liberal manner to members and visitors, and the local committee made efficient arrangements for the accommodation of all who desired it. There were the usual receptions, which were largely attended and much enjoyed. It is given to but few places to favor their guests with so pleasant a treat as a day at Niagara Falls.

The Buffalo people owe their best thanks to Mr. Secretary Grote, of their young Academy of Sciences, for his efficient agency in securing the meeting to their town on this memorable year, as Philadelphia was a powerful rival for the honor. It is through this little scientific society, which has had to struggle on with insufficient means, sustained by a few who were heartily interested, that the citizens of Buffalo have been roused to invite the convention and to extend to its members so cordial a welcome. We hope that the stimulus thus given to the public interest in scientific subjects will bear permanent fruit and result in establishing the Buffalo Academy upon a liberal and permanent foundation.

But, while Buffalo has done its duty admirably toward the Association, has the Association in turn done its duty to Buffalo? Is duty in such a case a wholly one-sided thing, or are men of science such lions that they pay off their hosts by their bare presence? We do not suppose that the hospitable Buffalonians had an eye to what was to be got back from their guests, but obligations were nevertheless incurred, and it is proper to inquire how they were met. The citizens of that town, having no experience, did as those of other towns always do on these occasions—promised themselves great pleasure in attending the sessions of the Association. They drifted in freely at the opening meetings, but, after being peppered for an hour with unintelligible terms, they generally withdrew in a quiet way, and with their ardor cooled for discussions that could but little interest people at large.

The obvious logic of the case must have been that, although this scientific convocation was occupied with its own avowed and proper business, yet so far as ordinary outside folks were concerned it was something of a "sell." Now, we venture to think that this is all wrong, and if the American Association for the Advancement of Science were more liberally managed, it would recognize an important duty that it owes the public in each city where it is invited to hold its sessions. Granting that its strict and special aim is the advancement of science by original contributions to its various branches, and that its proper work is necessarily technical, and to be carried on in the little meetings of the scientists themselves, it is nevertheless true that there is a side of science in which the public is deeply concerned, and such a body as this, which goes annually from city to city, and has a great power of influencing the people for good, has no right to ignore its responsibility. The people are constantly appealed to by scientific men to give their money, while they live and when they die, for carrying on scientific investigations that are necessarily and largely expensive. Scientific men, in fact, must depend upon the public, and be supported by it. They, therefore, incur obligations, and cannot escape them. If science is a beneficent agency for all, if scientific truth requires to be diffused that every grade of society may reap its benefits in some form, then men of science, who have the knowledge and the capacity to present it in familiar and popular forms, are bound to do what they can according to their gifts and opportunities to promote these objects. The American Scientific Association, every time it enters a new city to hold its meeting, should contribute something useful and valuable for the instruction and enlightenment of all classes. It is a peculiar opportunity which should not be thrown away, and there are always men present competent to do the work, and who would cheerfully enter into it if it were a part of the regular arrangements of the Association. The British Association has done its duty in this respect for years. It has provided for the delivery of outside lectures, popular lectures, lectures to working-men given to the people in large halls, by the best talent of the body, and such gentlemen as Carpenter, Tyndall, Spottiswoode, Frankland, Huxley, Roscoe, and others, have not hesitated to do their share of the work when called upon. Notwithstanding all our talk of progress and the education of the people, the old monarchical and aristocratic country is far ahead of us in these matters. The American Association seems strangely indifferent to this aspect of its usefulness. It shirks its palpable duty in giving impulse and direction to general scientific education, and this omission to provide instructive lectures for the people at its yearly meetings seems further to show that it cares nothing about scientific teaching in any shape for public purposes.

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### *THE AIR IN COURTS OF JUSTICE.*

Judge Monell is dead; and we are informed he died of the foul air of the court-rooms in which he had officiated. Why should court-rooms poison those who frequent them, like Calcutta Black-Holes? We have not been often in such places, but we were never in a court-room yet that we did not think a fit subject for the action of the grand-jury as an indictable nuisance from its bad ventilation. Lawyers seem to be a good deal behind the age in the appreciation of pure air. When the chemists have gone to different places after samples of foul air, they generally report the worst from court-rooms. The way these are constituted for breathing-purposes is an excellent example of the way things are generally done by Government. Court-houses are built by the State, and usually with a large regardlessness of expense. But they are the work of architects, and are constructed more for external ornament than internal use. They please the eye of the passer with their stateliness, and asphyxiate the judges within. Money is profusely spent, and the building unfit to be used. And so with all places where politicians congregate, and Government provides the edifice. There came a wail from Washington during the last session that our Congressmen were being stifled by the bad ventilation of the House of Representatives. Millions upon millions have been put into the structure, and the whole world is called upon to come and admire its grand proportions and imposing effect, while the legislators within are being suffocated. The best Government in the world strangles its lawgivers with mephitic gases instead of allowing them to breathe pure air. But, before sickness and death can come by poisonous inhalations, there are stages of atmospheric deterioration in which the mind only is affected. The brain, the immediate instrument of thought and feeling, receives and requires the largest proportion of pure arterialized blood of any portion of the body. This is necessary to its functions, so that we cannot think, remember, compare, reason, and judge well, except in pure air, which maintains the mind's organ in its highest vigor and keenest action. Long before judges die and Congressmen take sick they must pass through this stage of cerebral depression, blunting of the sensibilities, and perversion and deadening of the mental operations. How much of the stupidity of legislation and the miscarriage of its judicial application may be due to the muddled brains of lawmakers and judges from breathing the pestilential air of legislative halls and courts of justice, it may be impossible to tell, but the inquiry is suggestive. It is also pertinent to ask, What sort of education can these parties have had, to submit to these conditions, even to the destruction of health and life?

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### *THE "CONFLICT" AND THE "WARFARE."*

The anxiety with which historic works on the relations of science and religion are now sought is a fact of special interest, and we think it a salutary symptom of the state of the public mind. Science has opened the question, and the world is taking hold of it in earnest. "The History of the Conflict between Religion and Science," by Dr. Draper, while being most vigorously pooh-poohed by those who did not like it, has steadily made its way, through translation, into nearly all the Continental countries, and is at last so loudly called for even in benighted Spain that two editions of it by rival publishers are reported as having appeared in Madrid. What possible or conceivable hope is there that religion and science in that country can ever be brought into genuine amity until there is first an intelligent recognition of what have been their past relations? President White's brief but telling sketch of "The Warfare of Science," though first widely circulated in the pages of this magazine, had to be reprinted, and in a few weeks has reached a third edition in this country, while it has been republished in England, and will undoubtedly be translated, as it deserves to be, into the chief European tongues. The merit of these works, and the secret of their success, are not more due to the ability with which they have been prepared, or the manly and fearless tone with which they discuss questions of the gravest importance, than to their opportune appearance and adaptation to the wants of a rapidly-widening audience of thinking people in all countries. War-literature is always popular, but it is beginning to be seen that there are wars of opinion and conflicts of ideas carried on in the intellectual world which have at least an equal interest with the narratives of military campaigns and the records of carnage on fields of battle.

It is but an act of justice to Dr. Deems, of this city, to state that he replied to the article of Mr. Boyd in the June Monthly, entitled "Science and the Logicians." We were compelled to decline publishing the reply to cut off a controversy that would have consumed more space than we can allow to such discussions.

# LITERARY NOTICES.

The Five Senses of Man. By Julius Bernstein, Professor of Physiology in the University of Halle. With Numerous Illustrations. No. XXI. of the "International Scientific Series." Pp. 304.

The work intrusted to the accomplished Professor of Physiology at Halle, Dr. Bernstein, has been admirably performed. Aware of the importance of his undertaking, and that his work would promptly reappear in all civilized countries, the author has taken his time, and produced a volume second to none in the series to which it belongs, and which will be valued as an able and permanent contribution to physiological literature. Many works have appeared upon this general subject, of varied merit, but they have generally been more anatomical than physiological, and have dealt rather with the mechanism of sensation than with its processes and philosophy. Prof. Wilson's book, published several years ago, was a pleasant piece of rhetorical work, but wholly inadequate as a scientific discussion of the subject, even at that time. Dr. Bernstein has taken up the problem of the senses of man from the latest point of view reached by physiology and psychology, and, while very full and clear in his description of the instruments and apparatus of sensation, the strength of his book and its more especial claim to attention will be found in the lucid analysis which he gives of what may be called the psychical aspect of sense-activity. He views the senses as the biological gateways where impressions from the external world pass into the organism, and are transformed, through the wonderful endowments of the nervous system, into consciousness in the mental sphere. This is unquestionably the profoundest mystery in the realm of life, and the ultimate *how* of this transformation will probably forever remain one of Nature's impenetrable secrets. But all ultimate explanations are beyond the grasp of science, which completes its work when it has analyzed and established the conditions of phenomena. No doubt it would be interesting to solve the ultimate problems of Nature, were such a thing possible to the human mind, but it is only of importance to find out that which is capable of being known. Even this field is inexhaustible, and whatever explanation may be reached we are never certain that a deeper explanation is not still attainable. In this matter of the nature and operation of the senses great progress has recently been made, and physics, chemistry, physiology, histology, and psychology, have all contributed their separate rays to the illumination of the subject. Many points are unsettled, and many perplexities and obscurities remain to be cleared up; but there has still been an immense amount of efficient and successful work of research that required to be digested by some master-hand so as to be available for the common reader who has no time to master elaborate scientific treatises. It was not an easy thing to find a man competent, interested, and willing to undertake this task; but it fortunately fell into the right hands. Dr. Bernstein has proved himself to be not only possessed of the requisite knowledge, but to be an adept in the art of presenting it, as will be seen by the extract from his work given in the present number of the Monthly. He had a reputaion as a clear and skillful writer, which the present volume will enhance; while the translation does him justice, and presents his exposition in an attractive English form. This volume is one that might be well adopted as a text-book for our schools.

SIMILARITIES OF PHYSICAL AND RELIGIOUS KNOWLEDGE. By JAMES THOMPSON BIXBY. Pp. 266. New York: D. Appleton & Co. Price, $1.50.

OUR readers will be interested in the article on "Religion and Science as Allies," by Mr. J. T. Bixby. This gentleman is author of the volume under the foregoing title—a work written in a liberal spirit, with much discrimination and judicial fairness, and which aims to get down to the radical harmonies of religion and science. There is a steadily-deepening interest in the thinking world on the question of the relations of these two subjects which relates to both their analytical and historical aspects. Mr. Bixby's book-is one of the best representatives of a large class of works that are devoted to working out the fundamental relations of science and religion. The inquiry goes deep, and still involves the most radical disagreements among thinkers of different schools. Partial views must still be expected while thinkers remain partisans, for current scholarship is not yet broad enough to deal with a problem so comprehensive in a thoroughly synthetic and unifying way. But there is compensation from the number of earnest and vigorous minds that are taking it up on its various sides, and, from the thorough sifting which the subject will thus receive, we may expect a wider agreement and more pacific relations among the parties interested. The present work is written in the interest of peace, but the author does not shirk its difficulties, and is aware how large must be the mutual concessions before lasting concord can be gained. He is an independent thinker, who has studied carefully the later products of scientific literature, and treats them with marked critical ability. The volume is full of instruction, well presented, and we cordially recommend it to readers interested in this line of inquiry.

THE SCIENTIFIC BASES OF FAITH. By JOSEPH JOHN MURPHY, author of "Habit and Intelligence." Pp. xliv–474. 8vo. London: Macmillan & Co. 1873. Price $5.00.

WE regard this work as of unusual interest and value, and taken in connection with its predecessor, "Habit and Intelligence," it should be welcomed by those who desire a more harmonious adjustment of the relations among the thinkers and believers (often coexistent in the same person) of the present time. It is an attempt to "harmonize Scripture with science," that is say, to "try by how little distortion of the sense of Scripture, and by how little misrepresentation of the facts of science, the narratives of the Old Testament may be made to coincide with the facts disclosed by scientific research." Through twenty-nine chapters, with an "introduction" and a "conclusion," Mr. Murphy discusses such subjects as the relations of "Metaphysical and Positive Philosophy," "The Metaphysical Interpretation of Nature," "The Bases of Knowledge," "The Limits of our Knowledge," "The Proof of Deity from Intelligence and Design," "The Structure of the Universe," "Nature and the Religious Sense," "Immortality," "The Relation of History to Religion."

The author is, we believe, a clergyman of the lately disestablished Church of Ireland, and his views of Scripture inspiration and interpretation may fairly be called "broad," as that word is now understood in the English Church; but we rarely find a man who seems more reverent in spirit: courteous, critical, and fair, he is worthy of a patient, candid hearing, alike from those who hold very "conservative" views of the Bible and of orthodoxy on the one hand, and on the other from those who are inclined to think that the "age of faith" has passed away before the more certain and substantial things of the "age of science."

Mr. Murphy asserts it to be "as certain as history and philosophy can make it that science is absolutely independent of theology;" yet he insists that science and faith are closely related, and that no treaty of peace can be established on the assumption that they have nothing to do with each other. His view of their mutual relation is illustrated by reference to that between *matter and life*, and *life and mind*, *life* presupposing *matter* as its *basis*, *mind* presupposing *life* as its *basis*. So *science* (using the word in its largest meaning and application) is presupposed as the *basis of religion*, which he believes will ultimately be recognized as the summit and crown of all knowledge.

His plea for the validity and value of consciousness as a *base* of knowledge, and his demand for a place for the *metaphysical* method coördinate with the *inductive*, are suggestive and able. Belief in the past, trust in the reality of memory, in personal identity, in the uniformity of the order of Nature, and in an external world, is *metaphysical*—is made known by consciousness only, and is of the nature of faith.

We are reminded here from time to time, as we read, of Bixby's lately-published work on "Similarities of Physical and Religious Knowledge," but we have no space to attempt even an approach to a complete synopsis of the work, and must commend it to the personal examination of those interested.

Hay-Fever; or, Summer Catarrh: its Nature and Treatment: Including the Early Form, or "Rose Cold;" the Later Form, or "Autumnal Catarrh;" and a Middle Form, or "July Cold," hitherto undescribed; based on Original Researches and Observations, and containing Statistics and Details of Several Hundred Cases. By Geo. M. Beard, A. M., M. D., Fellow of the New York Academy of Medicine, etc. New York: Harpers. Pp. 266. Price, $2.00.

This is a painstaking book, that will hardly fail to prove instructive to the class of sufferers for whose benefit it has been prepared. Dr. Beard has supplemented his medical observations and experience of the disease, which he says is incorrectly termed "Hay-Fever," by an extensive series of inquiries put to patients in regard to numerous facts which it seemed impossible to get in any other way. He sent a circular containing fifty-five questions to a large number of persons, and received reports of some two hundred cases, giving much valuable information; and this, with his considerable personal practice, is made the basis of his treatment of the subject. In regard to the nature of the malady, he observes in the preface:

"The theory taught in this book, that this disease is a complex resultant of a nervous system especially sensitive in this direction, acted upon by the enervating influence of heat, and by one or several of a large number of vegetable and other irritants, has the advantage over other theories that it accounts for all the phenomena exhibited by the disease in this or in any other country.

"The transmissibility of the disease from parents to children; the temperaments of the subjects; the capricious interchanging of the early, the middle, and the later forms; the periodicity and persistence of the attacks, and their paroxysmal character; the points of resemblance between the symptoms and those of ordinary asthma; the strange idiosyncrasies of different individuals in relation to the different irritants; the fact that it is a modern disease, peculiar to civilization; the fact that it abounds where functional nervous disorders are most frequent, and is apparently on the increase *pari passu* with other nervous diseases; and, finally, the fact that it is best relieved by those remedies that act on the nervous system—all these otherwise opposing and inconsistent phenomena are by this hypothesis fully harmonized. Those, however, who are unwilling to accept this interpretation will in this work find a *résumé* that is meant to be both impartial and exhaustive of other theories, and of all known facts relating to this affection, wherever observed. . . . Bearing in mind that this work will find its readers mostly among the laity, and chiefly among the sufferers from the disease, the aim has been to avoid, so far as might be, purely technical words and phrases, and, while keeping strictly within the limits of science, to bring every point within the comprehension of those who know little or nothing of medicine, save what has been wrought into them by their own painful experiences with this distressing malady."

Report on the Hygiene of the United States Army, with Descriptions of Military Posts. By John S. Billings, Assistant Surgeon, U. S. A. Washington: Government Printing-Office. 1875. Pp. 567.

The author begins his report with an allusion to the difficulty experienced by army medical men in getting their recommendations on sanitary matters attended to by the officers in charge of the posts, and follows this with the order of 1874, defining the duties of the medical officer so far as they relate to the hygienic management of the soldiers. This order seems broad enough for all practical purposes, and, could the officers be got to coöperate in carrying out its provisions, the result would undoubtedly be a material lessening of disease and mortality in the army. But, as now managed, both disease and mortality are largely in excess of what they should be. From a table showing the ratio per thousand of mortality in the United States Army as compared with the mortality of males between twenty and forty years of age in civil life, it appears that the death-rate from disease among the soldiers is from twice to three times as great per thousand as among civilians. The author ascribes this partly to the character of the food, which is often deficient in fresh vegetables, but mainly to the habitations in which the soldiers are obliged to live. In many instances these are without provision for ventilation, are often much overcrowded, and are rarely furnished with adequate appliances for bathing and the maintenance of cleanliness of person. In the matters of clothing and hospital service the author considers the troops generally well provided for. The bulk of the report is taken up with descriptions of military posts, furnished by different members of the army medical corps.

EIGHTH ANNUAL REPORT ON THE NOXIOUS, BENEFICIAL, AND OTHER INSECTS OF MISSOURI. By C. V. RILEY, State Entomologist. Pp. 196. Jefferson City: Regan & Carter print.

THE noxious insects considered in this volume are the Colorado potato-beetle, canker-worm, army-worm, Rocky Mountain locust, and the grape phylloxera. One innoxious insect, the yucca-borer, is treated of. The loss sustained in the State of Missouri in 1875 from injury done to grains alone by the Rocky Mountain locust is estimated by Prof. Riley at $15,000,000. Accordingly, we are not surprised that the greater part of the annual report should be devoted to this insect. Several interesting questions regarding the natural history of the locust are discussed, such as its transformations, the habits of the unfledged locusts, the directions in which the young locusts travel, etc. It has been asserted that young locusts are led in their marches by "kings" or "queens," but this Prof. Riley declares to be an error. "Certain large locusts," he writes, "belonging to the genera *Acridinia* and *Œdipus* hibernate in the full-grown, winged state, and not in the egg-state, like the Rocky Mountain species always with us; their presence was simply more manifest last spring, when the face of the earth was bare. Hopping with the others, or falling into ditches with them, they gave rise to this false notion, and it is an interesting fact, as showing how the same circumstances at times give rise to similar erroneous ideas in widely-separate parts of the world, that the same idea prevails in parts of Europe and Asia."

THE GEOLOGICAL AGENCY OF LATERAL PRESSURE EXHIBITED BY CERTAIN MOVEMENTS OF ROCKS. By W. H. NILES. Pp. 15. Boston: Kingman print.

PROF. NILES has studied, in five different localities, the evidences proving the continued action of the lateral pressure occasioned by the earth's contraction. His general conclusions are 1.—That the rock at these localities has been brought into a compressed condition by a powerful lateral pressure, acting only in a northerly and southerly direction; and, 2. That, when opportunity is presented, the compressed rock expands with great energy.

GEOGRAPHICAL VARIATION AMONG NORTH AMERICAN MAMMALS. Also, Sexual, Individual, and Geographical Variation in *Leucosticte tephrocotis*. By J. A. ALLEN. Pp. 41. Washington: Government Printing-Office.

MR. ALLEN finds the variation in size, with latitude, to be surprisingly great in wolves and foxes, amounting in some species to twenty-five per cent. of the average size of the species, while in other species of the *Feræ* it is almost *nil*. Contrary to the general impression, the variation in size among representatives of the same species is not always a decrease with the decrease of the latitude of the locality, but is in some cases exactly the reverse.

TRANSACTIONS OF THE KANSAS STATE HORTICULTURAL SOCIETY (1875). Pp. 277. Topeka: G. W. Martin print.

THE State Horticultural Society of Kansas appears to be a very industrious and efficient body. Two meetings were held during the year 1875, and the proceedings are here fully reported. An important feature of the volume before us is the reports of the county vice-presidents. These officers are charged with the duty of organizing local horticultural societies, and of reporting annually to the society upon horticultural matters in their localities.

The Constants of Nature. By F. W. Clarke, S. B. Washington: The Smithsonian Institution.

In 1873 the Smithsonian Institution published Part I. of the above-named work, and we have now before us Parts II. and III., as also a first supplement to Part I. In this first part are given tables of specific gravities, boiling-points, and melting-points. Part II. is a table of specific heats for solids and liquids, and Part III. gives tables of expansion by heat for solids and liquids. In compiling these tables Prof. Clarke has expended a vast amount of labor—a labor of love, inasmuch as his services are rendered gratuitously.

Archivos do Museu Nacional do Rio de Janeiro. Rio de Janeiro: Imprensa Industrial. Pp. 30, quarto, with Plates.

The *Archivos* is published quarterly, and is the organ of the National Museum of Brazil. Its first object is to give an account of the contributions to science made by that institution, but it will also from time to time contain essays on scientific subjects from other sources. In the present number (which is the first) there are three articles, viz.: "Studies of the Shell-heaps (*Sambaquis*) of Southern Brazil," by Carlos Wiener; "On Some *Tangas*" (well translated "fig-leaves" in the *Nation*) "of Baked Clay used by the Ancient Inhabitants of the Island of Marajō," by Ch. Fred. Hartt; and "Studies upon the Morphological Evolution of the Tissues in Sarmentose Caules," by Ladislau Netto.

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## PUBLICATIONS RECEIVED.

The Kinematics of Machinery. By F. Reuleaux. Pp. 638. New York: Macmillan. Price, $7.50.

Elements of Latin Grammar. By G. Fischer, LL. D. Pp. 236. New York: Schermerhorn. Price, $1.25.

Forest Culture and Eucalyptus-Trees. By E. Cooper. Pp. 237. San Francisco: Cubery & Co.

Exploring Expedition from Santa Fé to the Junction of Grand and Green Rivers. By J. S. Newberry. Pp. 148. With Plates. Washington: Government Printing Office.

First Steps in Political Economy. By M. R. Leverson, Ph. D. Pp. 215. New York: Authors' Publishing Co. Price, $1.25.

The Ultimate Generalization. Pp. 56. New York: Somerby.

Chorea. By G. T. Stevens, M. D. Pp. 19. New York: Appletons.

The Study of Music. By E. B. Oliver. Pp. 10. Hartford: Case, Lockwood & Brainard.

Plastic Dressing in Fractures of Lower Extremity. By D. W. Yandell, M. D. Pp. 10. Indianapolis: *Journal* print.

Physiology of the Respiratory Apparatus. By J. Ott, M. D. Pp. 4. Chicago: Kissell & Co.

Guide to the Museum of the Academy of Natural Sciences of Philadelphia. Pp. 128.

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# MISCELLANY.

**A Preliminary Note on Menopoma Alleghaniense of Harlan.**—At the Buffalo meeting of the American Association for the Advancement of Science, Prof. A. R. Grote read a paper with the above title on the *Menopoma*, an aquatic salamander, with soft, leathery, scaleless skin, inhabiting the tributaries of the Mississippi River. After the examination of a large number of specimens, the characters separating the species *Menopoma Alleghaniense* and *fuscum*, as recently accepted by Cope, were found inconstant, and Grote comes to the conclusion that "there is only *one* and not *two* species inhabiting the water-shed of the Mississippi." After watching the habits of the animals in the aquarium, Grote succeeded in ascertaining the fact that the outer layer of the skin is shed as in snakes and toads, and is, in some cases at least, swallowed by the animal, since it was in one instance taken out of the mouth of the specimen. Grote succeeded in obtaining eggs laid on August 30th, and draws attention to the fact that the *Menopoma* puts on a "marriage-dress" during this period of its life, the tail broadening, and a plaited extension of the skin appearing along the sides of the body. The habits of the *Menopoma* seem to be nocturnal, and its eggs are laid along the muddy banks of the streams it frequents. The egg contains a yolk about the size of a pea floating in a glairy white fluid, surrounded by a membrane like that enveloping the albumen in a bird's-egg, and taking in a certain amount of water by endosmosis.

**Insect Parasites in Muddy Trout-Ponds.**—In the fall of 1873 the owner of a pond near Amsterdam, in this State, put into the pond some yearling trout. About the middle of last July a few dead fish were seen floating upon the water. On the tail of one of these dead fish was found "a very curious green bug, about the size of a pumpkin-seed; long legs, red eyes, and a long stinger." Hereupon the owner of the pond consulted Mr. Seth Green, and the latter expressed his belief that the insects were destroying the trout. "The cause is," he writes, "that you have no quick-running water, like a creek, with gravel bottom, running in your pond. By having such a place, when any insect is fastened on a trout, he will go to the quick-running water, and will soon rub it off. Putting trout in a pond with mud and weedy bottom that contains water-insects, and no stream flowing into it, is like tying a man's hands and placing him where there are plenty of mosquitoes, gnats, and black flies. The running water and gravelly bottom answer the same purpose in keeping the trout free from insects as our hands do in keeping the mosquitoes from us."

**Management of the Bedding in Sleeping-Cars.**—A writer in the *Sanitary Journal*, of Toronto, calls public attention to a source of danger existing in the sleeping-arrangements of certain railway-carriages. The beds in each section are opened out at night, after having been tightly closed for a period of twelve or fourteen hours. "Into these beds," says the author, "a stranger enters, probably partially recovered from some infectious disease, such as small-pox, scarlet fever, etc. He makes his exit, and at once these beds are closed and fastened down carefully again until the following night, when the same process of bed-making is observed, with a change of sheeting, as the case may be." The remedy suggested by the author does not appear to be sufficient: it consists simply of perforations in the bed-casings, with openings outward, so as not to communicate with the interior of the coach. But, if by this plan the germs of contagious disease are not destroyed, the bedding at least will be aired to some extent, and this will be no slight advantage.

**A Neglected Naturalist.**—Under the title of "A Neglected Naturalist," Mr. H. E. Copeland contributes to the *American Naturalist* a vindication of Constantine S. Rafinesque against the aspersions cast upon his scientific work by European and American critics. It is charged that the work done by Rafinesque only introduced confusion into botany and zoölogy by needlessly multiplying genera and species. But, according to the author, "thirteen genera, eight sub-genera, and sixteen species of the plants referred to in Gray's manual, are his. His writings on conchology have been considered worth editing by Binney and Tryon. Of our reptiles and batrachians four genera and six species bear his name. He described four genera and four species that are retained in the current literature treating of our mammals. The genus *Helmitherus* of birds was proposed by him." In 1820 Rafinesque published a "Natural History of the Fishes of the Ohio River." Mr. Copeland declares himself to be profoundly impressed by the accuracy of the work of Rafinesque as represented by this little volume. Of seventy-nine genera and one hundred and fifteen species of fishes known as inhabiting the Ohio and its tributaries twenty-nine genera and thirty-seven species were first described by this neglected naturalist, and the eliminating of seasonal and sexual forms from the rank of species, and the identifying of more of his genera on a better acquaintance with the fishes of the Ohio, will constantly make the ratio greater.

**Marsh-Water as a Vehicle of Ague-Poison.**—In his volume on "Practical Hygiene" the late Dr. Parkes adduces a number of facts to show that marsh-water is a vehicle of ague-poison. The more commonly-received opinion, however, is that the air of marshes is the sole cause of intermittent fevers. Certain observations made at Tilbury Fort, on the river Thames, appear to confirm Dr. Parkes's view. In the "Army Medical Blue-Book" it is stated that the troops at Tilbury Fort are supplied with water collected on the roofs of buildings, and stored in underground tanks at or below high-water mark. The officials at the neighboring railroad-station use spring-water pumped from a well. Now ague has, for a long time, been common among the troops at Tilbury Fort, and almost unknown at the railroad-station. During some cleansing and repairs to the tanks, spring-water was obtained from the latter source for several months together, during which time ague disappeared from among the soldiers at Tilbury, but on the tank-water being again brought into use, cases of ague again made their appearance, the disease ceasing on discontinuing that source of supply. Samples of water from these different sources were submitted to chemical analysis, when it was found that the amount of organic matter in the tank water was greatly in excess of that in the spring (railway-station) water, while the presence of vegetable and fungoid matter made it evident that there had been soakage of water from the surrounding marsh into the tanks.

**Dry Thunder-Storms.**—A correspondent in Oregon, Missouri, communicates some observations on weather phenomena, especially upon the influence of forests on rainfall. "When the earth has become dry, parched, and very warm, on occasion of thunder-storms, I have often," he writes, "noticed for hours, while it was thundering overhead, the mist, falling from the storm-clouds, to roll back, after nearly reaching the earth, in the form of lighter vapor. I think this rain, or mist, in falling, passed down to the stratum of very hot air on the earth's surface, and became a steam, large volumes of white vapor forming suddenly and rolling back and up. Now I am confident that, if the earth had been shaded by trees, this rain would have fallen on the ground.

"This phenomenon can be seen here every hot, dry season. It has, no doubt, escaped the attention of all but very close observers. Mine was called to it by a question asked while one of these dry thunder-storms was prevailing—a common thing—dry thunder-storms—thunder rattling overhead, but not a drop of rain falling. The white mist is not easily observed overhead, where all is light; but opposite to the sun, under the dark storm-cloud, it is very plain, and must attract attention."

**Fertilization of Plants.** — Mr. Thomas Meehan discovers in the "sleep" of plants an agent in their self-fertilization. The fertilization of the common *Claytonia Virginica* had been somewhat of a mystery to him, as, in view of the prevailing theory of cross-fertilization by insect agency, this plant ought not to be a self-fertilizer; but from repeated observation he was satisfied that no insects had visited plants that had yet seeded abundantly. Watching the process of fertilization, he found that the stamens on expanding fell back on the petals expanded during daylight. At night, when the flower closed, the petals drew the anthers up in close contact with the pistils. Cross-fertilization could be accomplished by insects if they visited the flower, but they did not, and actual fertilization only occurred in this way. In many cases, especially late in the season, the stamens recurve so much as to be in a measure doubled up by the nocturnal motion of the petals. The anthers were not drawn into contact with the stigmas in these cases, and, as a result, the flowers were barren.

In the *Ranunculus bulbosus*, our common buttercup, in the evening following the first day's expansion of the young flower, the immature anthers and the young stigmas would be found covered with pollen-grains. The inference would generally be, that this had been carried there by insects. But, as he had been especially on the lookout for insects as visitors to the buttercup, and feeling sure that none of any consequence had been to them, he examined these flowers carefully, and found that, on the first expansion of the flower, a single outer series of stamens burst their anther-cells simultaneously with the expansion of the flower, and, by contracting the cell-walls, ejected the pollen to the smooth petals, from which it easily fell to the immature anthers and stigmas, when the flower closed for the night.

Knowing that another species of buttercup, the *Ranunculus abortivus*, had fixed spreading petals which did not close at night, and which, though with comparatively large nectariferous glands full of a liquid secretion, was wholly neglected by insects, and yet had every flower seeding profusely, he was anxious to find, in view of his other discoveries, how these were fertilized. Visiting a wood after twilight, to ascertain if any nocturnal insects visited them, he found that, though the petals did not close at sundown, the slender pedicles drooped, inverting the flower, and in this way the pollen found its way from the petals to the stigmas without any difficulty whatever.

**Functions of the Root-Hairs of Plants.**—In an article published in the *Gardener's Monthly*, Prof. B. C. Halsted points out the functions of the "root-hairs" of plants. These so-called root-hairs are thread-like structures, consisting of elongated surface-cells of the root. These hairs absorb water out of the soil either by capillary attraction, or by the process of diffusion, or by osmotic action. It is a well-known fact that porous bodies absorb liquids to a greater or less extent. A dry cloth hung so that one corner will dip into water soon becomes saturated. This is capillary attraction, and has a place in root-absorption. From an extended study of the properties of liquids, the law of diffusion has been established, viz., that when two or more miscible liquids of different densities are placed in contact, interchange will take place till the whole liquid is homogeneous. This property of liquids will account for the movement of the absorbed sap to any part of the same cell—from the tip of the hair to its base But there is another kind of diffusion—*osmose*, or membrane diffusion. When liquids of different densities are separated by a thin membrane, diffusion takes place through this partition with a rapidity depending on the nature of the liquids and membrane, the greater flow being toward the denser fluid. The cell-wall of a root-hair is such a membrane, separating the denser liquid within the cell from the thinner one without; and, as this membrane is a living, growing one, it may be specially effective for osmotic action. From the function, position, and delicate structure of the root-hairs, at least one important practical conclusion can be drawn, viz., the importance of preserving them when a plant is to be potted or transplanted.

**The Philosophy of Dreams.**—Prof. Ferrier recently delivered, at the London Institution, a lecture on "Dreaming," explaining its phenomena by the results of his famous experiments on the localization of faculties in the brain. For each class of impressions there are, he said, special regions of consciousness in the brain. The impressions received are photographed on the brain, and are capable of being revived. But for this power of recalling them no knowledge would be possible. Memory, or the registration of sense-impressions, is the ultimate basis of all our mental furniture. Each piece of that furniture has its function, like the letters in a compositor's case. We have a sight-memory, a hearing-memory, etc. When thinking, or engaged in ideation, we are but recalling, as shown by Herbert Spencer and Bain, our original sensations and acts of cognition. Commonly the reproduction is very faint, but in some instances it is nearly or quite as vivid as the original sensation. This is especially true of poets, painters, religious enthusiasts, and others. Those portions of the brain which are most continuously in action during waking-hours require the longest rest during the hours of sleep. Hence the centres of attention would sleep while the functions allied to reflex actions would more easily waken.

The brain in sleep Prof. Ferrier compared to a calm pool, in which a stone causes ripples, liable to interruption by other ripples similarly caused. So the ripples of ideation get confused. But, again, the circle on the pool may not be interrupted, and then the ideation will be regular. The current of ideation may be coherent or incoherent. The most vivid association, which is commonly the latest, dominates over the rest. Dr. Reid, the metaphysician, once dreamed of being scalped—there was a blister upon his head. Dr. Gregory, from having a bottle of hot water at his feet, dreamed of walking up the crater of Etna. Visceral conditions are the most frequent sources of dreams; the hungry dream of feasts, the thirsty of water, the dropsical of drowning. Dr. Ferrier happily compares incoherent dreaming to the changes in a kaleidoscope. There is nothing new in dreams; the blind do not dream that they see, nor the deaf of music. In such cases there is a letter missing from the font of type. Our fancy is awake during dreams, and the faculties which should check it are asleep. Hence it is that nothing surprises us in dreaming.

**Locusts in Africa.**—In his work, "The Victoria Falls of the Zambezi," Eduard Mohr gives an impressive description of a flight of locusts witnessed by him in the region of the Vaal River. "I noticed," he writes, "on the western horizon what I took to be columns of smoke, rising higher and higher until they reached the zenith. I thought the bush must have been set on fire, for the whole of the horizon from the northwest to the southeast was already apparently enveloped in clouds of smoke. This, however, was caused by no fire, but by locusts. Presently a few, then dozens, then hundreds, then thousands, of locusts fell upon us, coming down in such heavy showers that the air was darkened with them; and through the whizzing, whirling veil they flung about us we could look with the naked eye at the sun, which, although high in the heavens, had the blood-red, rayless appearance usually peculiar to the time of setting." He adds that the natives, with their horses and cattle, as well as elephants and other wild ruminants, feed on them greedily; the author found them perfectly tasteless.

**Natural History in New Guinea.**—The Italian naturalist, D'Albertis, continues his explorations and studies of natural history in the island of New Guinea. He recently made the ascent of a mountain 1,200 feet high, on Yule Island, obtaining a good view of the plains watered by the Amama River. This river D'Albertis has partly ascended on several occasions; he states that it traverses an extensive and fertile district well suited for grazing. The Nicura River, into which the Amama debouches, is bordered by mangroves, eucalyptus, grass-trees, etc. He remarks that the natives appear everywhere ignorant of the uses of metals; and he is of opinion that Wallace and others are right in recognizing the existence of two races in the island. The aborigines he considers are confined to the western and interior portions, while the inhabitants in the other parts represent a taller, lighter-colored, and more intelligent race, which displaced the older tenants.

**Sulphide of Carbon as an Insecticide.**—The use of carbon sulphide is recommended by J. B. Schnetzler, of the Lausanne Academy, as a means of destroying the insects which infest herbaria and entomological collections. The Academy collection of Swiss flowering-plants having been attacked by *Anobium paniceum*, M. Schnetzler had a wooden box made large enough to contain five fasciculi of the herbarium, each composed of about 200 plants. Four ounces of carbon sulphide were poured into the five fasciculi; the box was tightly closed, and the whole left for a month. All the insects were destroyed, and no injury was done to the specimens, or to the papers to which they were fastened. The expense of the operation is very small. M. Schnetzler recommends that the boxes should be placed under a shed, as in case of the escape of vapor there might be danger of explosion. The same process may be employed for collections of insects.

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## NOTES.

During the present year the United States Fish Commission have placed in the Hudson River 4,580,000 young shad. The commissioners observe a steady increase in the supply of this fish. They ask, however, for legislation compelling a cessation of fishing on Sunday.

At the distance of 20 miles from Carter Station, on the Union Pacific Railway, is situated a remarkable coal-mine. It is about 4 miles in length, and consists of 16 veins, lying one above another, with a thin layer of sandstone intervening. The bottom vein is the thinnest (5 feet), while the one next above is over 75 feet in thickness. A few feet above this is a vein of 60 feet, another of 40 succeeding, and so on, making in all about 400 feet of coal. The veins slope at an angle of about 22°, and are very easy of access.

Prof. Riley, at a meeting of the St. Louis Academy of Science, exhibited a Colorado potato-beetle, which was so completely covered with a mite parasite that the point of a needle could not be placed on any part of the beetle's body without touching one of the parasites. He estimated the number of mites at 800, and they had killed the beetle. Aside from the toad and other reptiles, the crow, the rose-breasted grossbeak, and domestic fowls, among birds which prey on the *Doryphora decemlineata*, Prof. Riley had in his report figured or described no less than 23 insect-enemies that attack and kill it. Only one of these is a true parasite, and this mite makes the second. It belongs to the family *Gamasidæ*.

At a meeting held in London, in aid of the fund for a memorial to the late Dr. Parkes, a resolution was adopted which declared it desirable that the memorial should take the form of a museum of hygiene. A list of subscriptions was read amounting to £675.

Everywhere in Germany carrier-pigeons are being trained for service in time of war, to keep up communication between the garrisons of besieged fortresses and the military authorities. Another use of these pigeons is suggested, viz., as a means of conveying intelligence from light-ships to the nearest port, in case the former are in need of succor.

The London publisher, Murray, announces a new work by Mr. Darwin, entitled "The Results of Cross and Self Fertilization in the Vegetable Kingdom."

By subcutaneously injecting into animals concentrated solutions of sodic lactate, Preyer produces in them a state apparently identical with normal sleep. This confirms the theory which attributes the drowsiness caused by fatigue to the presence in the blood of certain compounds (as lactic acid) produced by the disintegration of nervous and muscular tissue.

Some curious statistics illustrating the liability of the eye to injury have been compiled by Drs. Zander and Geissler. They assume that the mean superficies of the human body is about fifteen square feet, and that the mean superficies of the orbital opening is about 180 square lines, from which it should follow, if all parts were equally exposed to injury, that lesions of the eye would bear to lesions of other parts of the body the proportion of about one in 600. As a matter of fact, the actual proportion is more than twenty times as great, or about 36 in 1,000.

It has been shown by experiment that Prussian blue in oil is the most stable of pigment colors. Aniline colors, on the contrary, are the most fleeting; indeed, they are unsuitable for use by the painter. Photographs tinted with aniline colors soon lose their tints, and the colors are often seen fading while the pictures are yet exposed for sale.

M. Lecoq de Boisbaudran, the discoverer of gallium, has succeeded in reducing to the metallic state about ten centigrammes of the new metal. When pure, gallium melts at the very low temperature of 85° Fahr. It adheres readily to glass, forming a whiter mirror than mercury, but its low fusion temperature makes it practically useless for this purpose. It oxidizes very slightly when heated to redness, but does not volatilize.

A patient in the Royal Infirmary, Edinburgh, who suffered from cancer of the tongue, had the organ amputated, except about half an inch. The operation was successful and the patient now speaks quite distinctly; in doing so he seems to tilt upward and forward both the hyoid bone and the larynx.

At the National Glass Company's works, Bellaire, Ohio, lamp-chimneys are made by a process resembling that of De la Bastie. A local newspaper writer mentions having seen an eightpenny-nail driven through a board an inch and a half thick with one of these chimneys of hardened glass.

The nickel-mine near Lancaster, Pennsylvania, yields about 6,000 tons of ore per year. Eleven shafts have now been sunk, ranging from 110 to 140 feet in depth, and connected by tunnels underneath. The number of men employed at the mine is 200.

Carbon occurs in the heavenly bodies in three forms, according to Prof. J. Lawrence Smith, viz.: the gaseous form, as detected by the spectroscope in the attenuated matter of comets; the solid form, impalpable in its nature and diffused in small quantities through pulverulent masses of mineral matter that come to the earth from celestial regions; and the solid form, compact and hard, resembling graphite, and this is imbedded in metallic matter that comes from regions in space. It is not necessary to assume that this cosmical carbon has an organic origin.

A prize of five hundred francs has been offered by M. Paul Bert for the best means of protecting the lives of aëronauts and mountain-climbers in circumstances where cold and rarefied air become dangerous. His prize is open to competition till the last day of the present year.

A fireman's suit, invented by a Swede named Oestberg, is made in two layers, the inner one of India-rubber, the outer one of leather, the head being protected by a helmet resembling that worn by divers. At the girdle is fixed a piece of hose, which serves both for air and water. The air-pipe, fed from two blowers, is placed inside the water-pipe, and brings the air, after being cooled by the surrounding water, into the inner part of the dress. The air inflates the costume, passing away through the two small openings made for eye-pieces. The current of air not only keeps the inclosed body cool, but drives smoke and flame away from the eyes. At the back the water-pipe divides, one branch serving as an extinguisher, the other passing into the outer coating of the dress, the stream being distributed over the whole outer surface. With the apparatus on, the inventor stood in the middle of a pile of burning shavings and logs without taking the least harm.

An epidemic resembling cholera appeared among the cats in Delhi last year. The disease was not known to extend beyond the walls of the city, nor was it confined to any quarter. It gradually declined, and fully disappeared about September 20th, although the cholera did not cease till near the end of November. The number of cats carried off by the disease was estimated at 500. The symptoms were in almost every respect identical with those of cholera. Experiments were made with cholera-virus, which was found to communicate an analogous disease to the cats.

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